IOWA DEPARTMENT OF
NATURAL RESOURCES

2015 Iowa Statewide Greenhouse Gas Emissions Inventory Report

Technical Support Document

Required by Iowa Code 455B.104

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Iowa Department of Natural Resources
502 E. 9th Street
Des Moines, IA 50319

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Acronyms and Key Terms

AEO	Annual Energy Outlook
AR4	Fourth Assessment Report
BOD	biochemical oxygen demand
BOF	blast oven furnace
Btu	British thermal unit
CAMD	Clean Air Markets Division
CH_4	methane
CO_2	carbon dioxide
COMET	Carbon Management and Evaluation Online Tool
CRP	Conservation Reserve Program
DNR	Iowa Department of Natural Resources
DOT	United States Department of Transportation
EAF	electric arc furnace
EIA	United States Energy Information Administration
EIIP	Emission Inventory Improvement Program
EPA	United States Environmental Protection Agency
FERC	Federal Energy Regulatory Agency
FIDO	Forest Inventory Data Online
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GHG	greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
HDGV	heavy duty gas vehicle
HDDV	heavy duty diesel vehicle
IDALS	Iowa Department of Agriculture and Land Stewardship
IDOT	Iowa Department of Transportation
IEA	International Energy Agency
ILPA	Iowa Limestone Producers Association
IPCC	Intergovernmental Panel on Climate Change
LDC	local distribution company
LDDT	light duty diesel truck
LDDV	light duty diesel vehicle
LDGT	light duty gasoline truck
LDGV	light duty gasoline vehicle
LFGTE	landfill gas to energy
LULUCF	land use, land use change, and forestry

Acronyms and Key Terms (Continued)

MC	motorcycle
MMtC	million metric tons carbon
$MMtCO_2e$	million metric tons carbon dioxide equivalent
MSW	municipal solid waste
N	nitrogen
NEI	National Emissions Inventory
NRCS	Natural Resources and Conservation Service
NO_3-	nitrates
NO_2-	nitrites
N_2O	nitrous oxide
ODS	ozone depleting substance
OECD	Organization for Economic Co-operation and Development
PET	polyethylene terephthalate
PHMSA	Pipeline and Hazardous Materials Safety Administration
PS	polystyrene
PVC	polyvinyl chloride
SIT	State Inventory Tool
TAR	Third Assessment Report
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VMT	vehicle miles traveled
WRI	World Resources Institute

Chapter 1 – General Calculation Method

Iowa Code 455B.104 requires that "by December 31 of each year, the department shall submit a report to the governor and the general assembly regarding the greenhouse gas (GHG) emissions in the state during the previous calendar year and forecasting trends in such emissions…." This Technical Support Document (TSD) provides documentation and additional calculations to support the *2015 Iowa Statewide Greenhouse Gas Emissions Inventory* Report, which is available at http://www.iowadnr.gov/Environmental-Protection/Air-Quality/Greenhouse-Gas-Emissions. Total Iowa GHG emissions from 2005 – 2015 are provided in Appendices A and B of this document.

This is a "top-down" inventory based on statewide activity data from agriculture, fossil fuel combustion, industrial processes, natural gas transmission and distribution, transportation, solid waste, and wastewater treatment. It also includes carbon emitted or sequestered from land use, land use change, and forestry (LULUCF).

Method

Emissions were calculated using the most recent version of the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT)[1] and using available Iowa-specific activity data. The energy and industrial processes sectors were also supplemented with GHG emissions data submitted by individual Iowa facilities to the federal GHG reporting program (40 CFR 98).

The calculation methods in the SIT are based on the August 2004 version of EPA's Emission Inventory Improvement Program (EIIP) guidance for greenhouse gases (ICF 2004). The individual modules for each sector are Excel workbooks populated with emission factors and default activity data for years 1990 – 2013/2014, but allow the user to enter better state-specific activity data when it is available. Detailed information on the activity data used is provided in the corresponding chapter for each sector, under the "Method" heading. The individual modules then auto-calculate the resulting GHG emissions from each sector. The results from each module were then tabulated in an Excel spreadsheet. The SIT Projection Tool was then used to forecast emissions to 2030. The SIT modules and their corresponding chapters in this Technical Support Document are listed in Table 1 on the next page. The coal module was not used as there are no coal mines currently operating in Iowa.

[1] The SIT may be requested at https://www.epa.gov/statelocalclimate/download-state-inventory-and-projection-tool.

Table 1: TSD Chapters and Corresponding SIT Modules

TSD Chapter	SIT Module	Release Date	Pollutants Addressed
Agriculture	Ag	02/15/16	CH_4, N_2O
Energy	CO_2FFC	02/15/16	CO_2
	Stationary Combustion	02/15/16	CH_4, N_2O
Industrial Processes	IP	06/20/16	CO_2, N_2O, HFC, PFC, SF_6
Natural Gas Transmission and Distribution	Natural Gas and Oil	02/15/16	CH_4
Transportation	Mobile Combustion	02/15/16	CO_2, CH_4, N_2O
Waste	Solid Waste	05/09/16	CO_2, CH_4
	Wastewater	02/15/16	CH_4, N_2O
Land Use, Land Use Change, and Forestry (LULUCF)	LULUCF	02/15/16	CO_2, N_2O
Indirect Emissions from Electricity Consumption	Electricity Consumption	05/09/16	CO_2
Future Emissions	Projection Tool	12/01/14	CO_2, CH_4, N_2O, HFC, PFC, SF_6

Global Warming Potentials (GWP)

The potency of various greenhouse gases can vary, so greenhouse gas emissions are typically converted to a unit of measure called carbon dioxide equivalent (CO_2e) that allows for better comparison of the impact of different greenhouse gases. CO_2e is calculated by multiplying the mass amount of each greenhouse gas by its global warming potential (GWP) and then summing the resulting value. CO_2e was calculated using Equation 1 below:

Equation 1:

$$tons\ CO2e = \sum_{i=0}^{n} GHGi\ x\ GWPi$$

Where:
GHG_i = Mass emissions of each greenhouse gas
GWP_i = Global warming potential for each greenhouse gas
n = the number of greenhouse gases emitted

On November 29, 2013, the U.S EPA starting using the GWPs from the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) (IPCC 2007) in its programs and reports, including using it for the first time in the national greenhouse gas inventory for 1990 – 2013. DNR intends to use the IPCC AR4 GWPs in future reports, but for the purposes of this report, DNR continued to calculate emissions using the GWPs from Third Assessment Report (IPCC 2001) as it has historically used. Any CO_2e emissions data from EPA was adjusted for the IPCC TAR GWPs. The GWP values used are shown in Table 2 on the next page.

Table 2. Global Warming Potentials

Pollutant	GWP used by DNR (IPCC TAR 2001)	GWP used by EPA as of 11/29/13 (IPCC AR4 2007)
Carbon Dioxide (CO_2)	1	1
Methane (CH_4)	21	25
Nitrous Oxide (N_2O)	310	298
Sulfur Hexafluoride (S_F6)	23,900	22,600
Hydrofluorocarbons (HFC)	Vary by pollutant – For a complete list, refer to DNR's "Estimation of Greenhouse Gas Emissions" guidance document.	
Perfluorocarbons (PFC)		

Benefits of GHG Inventories

Benefits of reports like this include the evaluation of emissions trends and development of a baseline to track progress in reducing emissions. A state-specific inventory also provides a more in-depth analysis and more accurate inventory of emissions compared to national emissions.

Chapter 2 - Agriculture

This chapter includes non-energy greenhouse gas (GHG) emissions from livestock and crop production in Iowa. GHG emissions from fossil fuel-fired agricultural equipment are discussed in *Chapter 6 – Transportation* and carbon emissions and sinks from agriculture are discussed in *Chapter 9 – Land Use, Land Use Change, and Forestry (LULUCF)* of this document.

GHG emissions are emitted from four agricultural sectors in Iowa – enteric fermentation, manure management, agricultural soils, and agricultural burning. The GHGs emitted are methane (CH_4) and nitrous oxide (N_2O). Table 3 below summarizes the source of GHG emissions in each sector. N_2O emissions from rice cultivation were not included as rice is not grown in Iowa (USDA 2016b).

Table 3: Sources of Agricultural GHG Emissions in Iowa

Sector		GHGs Emitted	Source of Emissions
Enteric Fermentation		CH_4	Microbial activity in the digestive systems of dairy cattle, beef cattle, sheep, goats, swine, and horses.
Manure Management		CH_4 N_2O	Decomposition of manure during storage and treatment of livestock manure.
Agricultural Soils	Residues, legumes, and histosols	N_2O	Biological nitrogen fixation by crops, crop residues remaining on fields, and cultivation of high organic content soils (histosols).
	Fertilizers	N_2O	Application of manure, fertilizers, etc. to soils and leaching/runoff of nitrogen into ground or surface water.
	Animals	N_2O	Animal excretions directly on to soils such as pastures.
Agricultural Burning		CH_4 N_2O	Burning of crop residues.

<u>Method</u>

GHG emissions from agriculture were calculated using the United States Environmental Protection Agency's (EPA) State Greenhouse Gas Inventory Tool (SIT) draft agriculture module dated February 15, 2016 (ICF 2016a and 2016b).

Enteric Fermentation

The SIT calculates CH_4 emissions from enteric fermentation by multiplying various livestock populations by an annual CH_4 emission factor (kilograms CH_4 per head). The data sources for the animal populations used are listed in Table 4 on the next page. The number of "Feedlot Heifers" and "Feedlot Steers" was derived by applying a 35/65 heifer/steer ratio to the "Total Number on Feed".

Manure Management

This sector includes CH_4 and N_2O emissions from manure when it is being stored and treated in a manure management system. In general, CH_4 emissions increase in more anaerobic (lacking oxygen) conditions while N_2O emissions increase under aerobic conditions (Strait et al. 2008). The same dairy cattle, beef cattle, sheep, goat, swine, and horse populations were used as for the enteric fermentation sector for consistency. Several other animal types were added as shown in Table 4.

Table 4: Animal Populations

Animal Type	Year	Data Source
Dairy cattle	2015	2015 Iowa Agricultural Statistics Bulletin (USDA 2015)
Beef cattle		
Sheep		
Goats	2012 used as proxy for 2013, 2014 and 2015	2012 Census of Agriculture (USDA 2014a)
Horses		
Breeding swine	2015	2015 Iowa Agricultural Statistics Bulletin (USDA 2015)
Market swine under 60 lbs.[2]		
Market swine 60 – 119 lbs.[3]		
Market swine 120 – 179 lbs.		
Market swine over 180 lbs.		
Broilers	2012 used as proxy for 2013, 2014 and 2015	2012 Census of Agriculture (USDA 2014a)
Chickens		
Hens		
Pullets		
Turkeys		

In addition, the number of "Sheep on Feed" and "Sheep off Feed" were derived by applying a 6.5/93.5 on feed/off feed ratio to the total number of sheep.

Agricultural Residue Burning

Burning of cropland is not a typical agricultural practice in Iowa. According to Iowa State University Extension and Outreach,

> *"Burning corn and soybean fields is just NOT a practice that is used in Iowa or many other Midwest states as a way of preparing the fields for planting a subsequent crop. Yes, there are rare occasions were corn residue is burnt off a field but it would not even be 1% of the crop acres. An example would be if the residue washed and piled up in an area it may be burnt to allow tillage, planting and other practices to occur. Another rare occasion is when accidental field fires occur during harvesting of the corn crop. But again this would be less than 1% of the crop acres."* (Licht 2015).

The SIT over-estimates agricultural fires, as it assumes that 3% of Iowa corn, soybean, and wheat field residue is burned annually. The *Year 2000 Iowa Greenhouse Gas Emissions Inventory* notes that **"**According to expert opinion, even this lower estimate [3%] is thought to be too large in Iowa because burning is mostly a maintenance tool for conservation plantings, which are not extensive" (Wollin and

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[2] SIT uses the category of market swine under 60 lbs., but USDA uses the category of market swine under 50 lbs.

[3] SIT uses the category of market swine 60 – 119 lbs., but USDA uses the category of market swine 50 - 119 lbs.

Stigliani 2005). The DNR has been working with EPA emission inventory staff for several years to refine estimates for agricultural fires in the EPA's National Emissions Inventory (NEI) and the DNR's annual greenhouse gas inventories (DNR 2015, Pouliot 2015 and Stein 2015).

For 2014, DNR staff reviewed the details of 1,008 fires that were reported to Iowa DNR by local fire departments (Kantak 2015) as shown in Table 5. Staff found that:

- 39 of the fires were truly agricultural fires, with 38 of 39 being fires being purposely set on grass lands enrolled in the Conservation Reserve Program, and 1 fire in a field of millet. No corn field or soybean field fires were reported to DNR.
- 309 of the fires were identified as being prescribed fires (fires ignited by management actions to meet specific objectives): 166 on state land, 101 on private land, 37 on county land, 5 on federal land.
- 660 of the fires were identified as being wildfires. 7 were accidental fires in cornfields that were started by overheated harvesting equipment. Several were wildfires that spread when trash or brush burning spread out of control to a nearby field or ditch.

Table 5: Fires in 2014 Reported to Iowa DNR

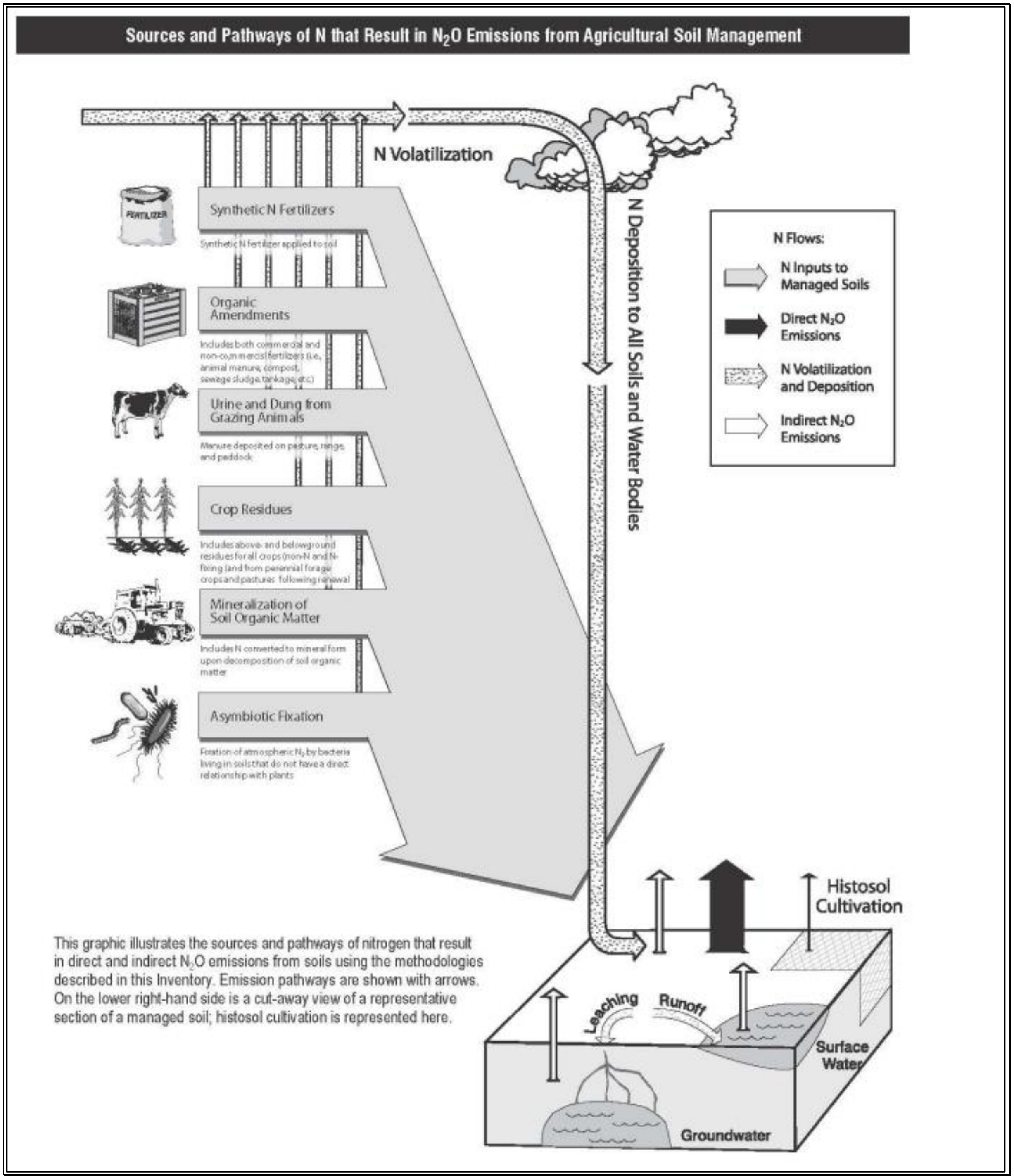
Type of Fire	No. of Fires in 2014 Reported to Iowa DNR	Total Acres Reported	Average Acres Burned
Agricultural Fires	39	1,981.4	50.8
Prescribed Fires	309	14,701.7	47.6
Wildfires	660	12,218.6	18.5
Total	**1,008**	**28,901.7**	**28.7**

There are several discrepancies between the pollutants EPA calculates for agricultural fires in the NEI (EPA 2015) and the SIT (ICF 2016a). EPA calculates carbon dioxide (CO_2) and methane (CH_4) emissions in the NEI, but calculates emissions from methane (CH_4) and nitrous oxide (N_2O) in the SIT. In addition, the NEI calculates emissions from the burning of grasses and CRP lands, but the SIT only calculates emissions from crops. EPA calculates emissions from the burning of grass and pasture lands in the national GHG inventory, but not from crops (EPA 2016). Due to these discrepancies, emissions from agricultural residue burning were not included in this inventory. Resolving this discrepancy continues to be an area of future improvement in the inventory.

Agricultural Soils

N_2O emissions in the agricultural soils sector occur from many different pathways as shown in Figure 1 on the next page (EPA 2016). N_2O is emitted when the natural processes of denitrification and nitrification interact with agricultural practices that add or release nitrogen (N) in the soil profile. Denitrification is the process of converting nitrate to nitrogen gas. It is carried out by microorganisms in an oxygen-lacking environment. Nitrification occurs when ammonia is converted to nitrites (NO_2-) and nitrates (NO_3-). It is carried out by specialized bacterial and naturally occurs in the environment.

Figure 1: Sources and Pathways of N2O Emissions in Ag Soils (EPA 2016)



Direct N_2O emissions occur at the site of application of both synthetic and organic fertilizers to the soil, production of N-fixing crops, and integration of crop residues into the soil by practices such as cultivation. Indirect emissions occur when N is made available or is transported to another location following volatilization, leaching or runoff, and is then converted to N_2O (EPA 2016).

Plant Residues and Legumes

2014 crop production data for alfalfa, corn for grain, oats, soybeans, and wheat (USDA 2016b) was used to calculate N_2O from nitrogen-fixing crops, including alfalfa and soybeans, and nitrogen returned to soils during the production of corn for grain, wheat, oats, and soybeans.

Soil Cultivation - Nitrous Oxide (N_2O)

N_2O is also emitted during the cultivation of highly organic soils called histosols. May 2011 soil survey data from the Natural Resources and Conservation Service shows there are just over 70,000 acres of histosols in Iowa (Sucik 2011a and 2011b). The quantity of histosols that are cultivated is not currently available (Bedmarek 2012), so the DNR estimated the number of cultivated histosol acres by multiplying the acres of histosols by the annual percentages of Iowa cropland that are corn and soybeans (USDA 2016b) and by the average percentage of each crop that is tilled (USDA 2015). However, this may be an overestimation as according to former State Soil Scientist, Michael Sucik, "…all Histosols are listed as hydric soils and are eligible for the Wetland Restoration Program as CRP [Conservation Reserve Program] practices that require wetlands. Also, a Histosol would require some type of artificial drainage in order to be consistently row cropped" (Sucik 2011a).

Soil Tillage Practices

Carbon may be emitted when soils are tilled. However, carbon may also be sequestered when soil conservation practices are used (no-till or reduced tillage), are converted to the Conservation Reserve Program, or are converted grass, trees or wetlands. This balance between emissions and sequestration is called the soil carbon flux. The SIT does not include the ability to calculate emissions from soil carbon flux from tillage practices.

Practicing no-till for many consecutive years produces the greatest carbon sequestration. When soil is tilled the soil becomes oxygenated, increasing microbial activity and releasing stored carbon. However, there is uncertainty in the amount of carbon stored and released. Scientific studies and literature reviews such as those by Baker et al. (2007) and Blanco-Canqui and Lal (2008) have created uncertainty in this area, while other studies such as those by Franzluebbers (2009) and Boddey et al (2009) dispute them. According to the USDA's "*'No-Till" Farming is a Growing Practice",* there is much uncertainty in the interaction between tillage practices, carbon, and other greenhouse gases" (USDA 2010). A 2007 study by West and Six explains that, "*The extent to which soil C accumulation occurs after a reduction in tillage intensity is determined by the history of land management, soil attributes, regional climate, and current carbon stocks"* (West and Six 2007). The relationship between tillage and nitrogen oxides (N_2O)

is also not completely certain. Several studies have observed increases, decreases, and no change in N_2O when soil is tilled (USDA 2010).

The complexity of calculating soil carbon flux is described in USDA's *Science-Based Methods for Entity-Scale Quantification of Greenhouse Gas Sources and Sinks from Agriculture and Forestry Practices*. This 605-page document was developed to create "a standard set of GHG estimation methods for use by USDA, landowners, and other stakeholders to assist them in evaluating the GHG impacts of their management decisions" (Eve 2014). It recommends that soil organic carbon stocks are calculated by modeling with the DAYCENT model. At this time the DNR does not have the required data inputs or capability of running the DAYCENT model.

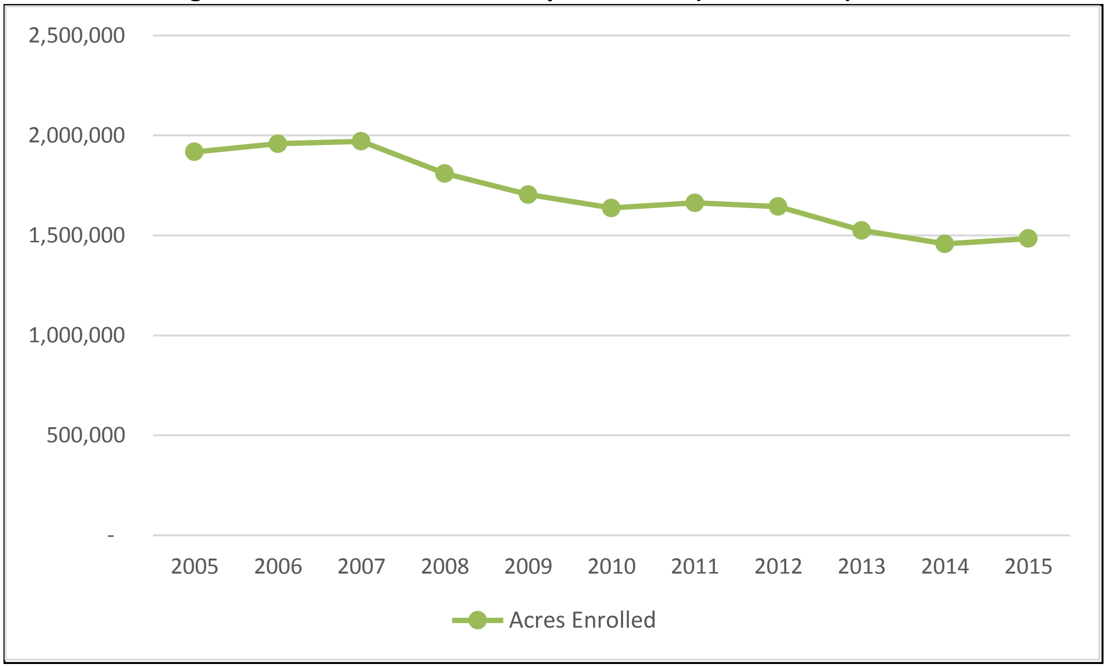
The USDA has also established seven regional climate change offices, offering climate hazard and adaptation data and services to farmers, ranchers, and forest landowners. The NRCS, a department within the USDA, has also launched a program called Carbon Management and Evaluation Online Tool (COMET-FARM) that allows users to calculate how much carbon is removed from the atmosphere from certain conservation efforts. The COMET-FARM website explains that:

> *The tool guides you through describing your farm and ranch management practices including alternative future management scenarios. Once complete, a report is generated comparing the carbon changes and greenhouse gas emissions between your current management practices and future scenarios (NRCS 2015).*

COMENT-FARM is not designed to calculate statewide greenhouse gas emissions from farming and ranching. It requires specific data inputs for each individual farm. However, if NRCS should publish results from the tool in the future, the DNR may include them in future inventory reports.

While the DNR is unable to quantify agricultural soil carbon flux at this time, it is known that cumulative Iowa acres in the CRP program are trending downward as shown in Figure 2 below. This indicates that the amount of carbon stored in agricultural soils *may* be decreasing as more soil is tilled each year. However, any effects from cover crops were not considered. This may be a future inventory improvement.

Figure 2: Acres Enrolled in CRP by Fiscal Year (USDA 2016a)



Fertilizer Utilization

The DNR calculated fertilizer emissions for 2015 using fertilizer tonnages from the Iowa Department of Agriculture and Land Stewardship's (IDALS) *Fertilizer Tonnage Distribution in Iowa* report (IDALS 2016). The IDALS fertilizer data is provided per the 2015 growing season, which is from July 2014 – June 2015. The 2015 growing season was then used as a proxy for the 2016 growing season (July 2015 – June 2016).

Adjustments

As shown in Table 6, 2014 emissions from enteric fermentation, manure management, and agricultural soils have been updated since the DNR's 2014 GHG Inventory Report was published in December 2015. This is because the activity data (such as animal populations or fertilizer application) used to calculate emissions in the previous report has been updated by either USDA or IDALS. In addition, 2012 and 2013 manure management emissions were also recalculated to correct errors made the poultry populations entered into the SIT and reported in the 2014 GHG Inventory Report.

Table 6: Recalculated Agriculture Emissions ($MMtCO_2e$)

	2012		2013		2014	
Sector	Value Published Dec. 2015	Updated Value	Value Published Dec. 2015	Updated Value	Value Published Dec. 2015	Updated Value
Enteric Fermentation					6.76	6.85
Manure Management	8.26	8.40	8.48	8.59	8.36	8.47
Agricultural Soils					20.92	20.94

Enteric Fermentation and Manure Management

Several animal populations were updated with more recent values as shown in Table 7. In addition, emissions changed because the enteric fermentation emission factors and manure management volatile solids vary by year.

Table 7: Updated Animal Populations

Animal Type	2014 Value used in 2014 Inventory Published Dec. 2015		Updated 2014 Value	
	Population	Data Source	Population	Data Source
Beef cows	885,000	2014 Iowa Agricultural Statistics Bulletin (USDA 2014b)	895,000	2015 Iowa Agricultural Statistics Bulletin (USDA 2015)
Beef replacement heifers	150,000		160,000	
Heifer stockers	620,000		640,000	
Steer stockers	1,240,000		1,270,000	
Calves	420,000		450,000	
Hens (Layers)	59,889,000	Unclear – errors	52,218,870	2012 Census of Agriculture (USDA 2014a)
Pullets	14,038,000		12,565,630	
Chickens	69,000,000		64,784,500[4]	

Agricultural Soils

The agricultural soils emissions were recalculated using a revised 2014 production value for soybeans, which was revised by USDA from 505,730,000 bushels to 498,270,000 (USDA 2016b). This changed the 2014 emissions by approximately 0.12 $MMtCO_2e$. Emissions from fertilizers were recalculated using actual fertilizer usage data for 2014 (IDALS 2016) instead of the proxy data previously used.

<u>Results</u>

GHG emissions from agriculture increased 2.68% from 2014 – 2015 and increased 15.84% from 2005 – 2015. Gross GHG emissions from agriculture were 36.26 $MMtCO_2e$ in 2015, or 28.85% of Iowa's total gross GHG emissions. This total does not account for any carbon sinks from agriculture. Sinks are discussed in *Chapter 9 – Land Use, Land Use Change, and Forestry*. The majority of agricultural emissions (57.64%) are from soils as shown in Table 8 and Figure 3 below.

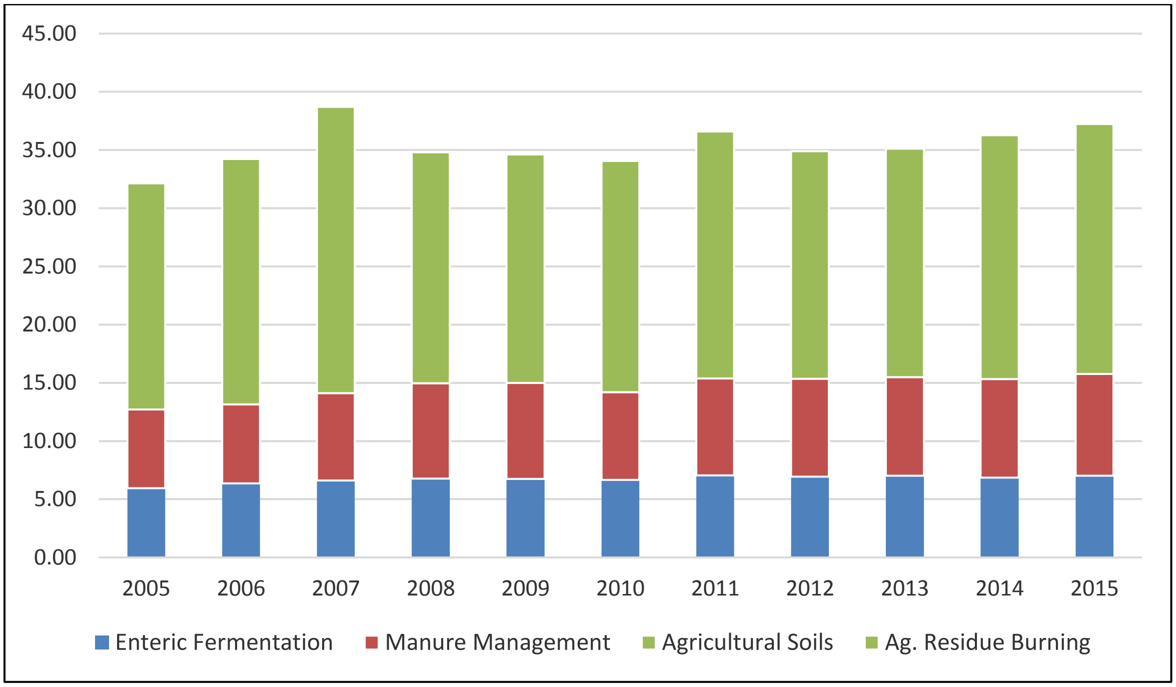
Table 8: Gross GHG Emissions from Agriculture ($MMtCO_2e$)[5]

Category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Enteric Fermentation	5.95	6.35	6.62	6.77	6.74	6.67	7.04	6.95	7.02	6.85	7.02
Manure Management	6.77	6.80	7.48	8.19	8.25	7.53	8.34	8.40	8.59	8.47	8.75
Agricultural Soils	19.42	21.10	24.63	19.85	19.63	19.86	21.22	19.56	19.61	20.94	21.46
Ag. Residue Burning	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Total	**32.14**	**34.25**	**38.73**	**34.81**	**34.63**	**34.07**	**36.61**	**34.90**	**35.22**	**36.26**	**37.23**

[4] The 2012 Census of Agriculture doesn't specifically list "chickens", so the number of chickens were assumed to equal the number of layers plus the number of pullets.

[5] Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 3: Gross GHG Emissions from Agriculture ($MMtCO_2e$)



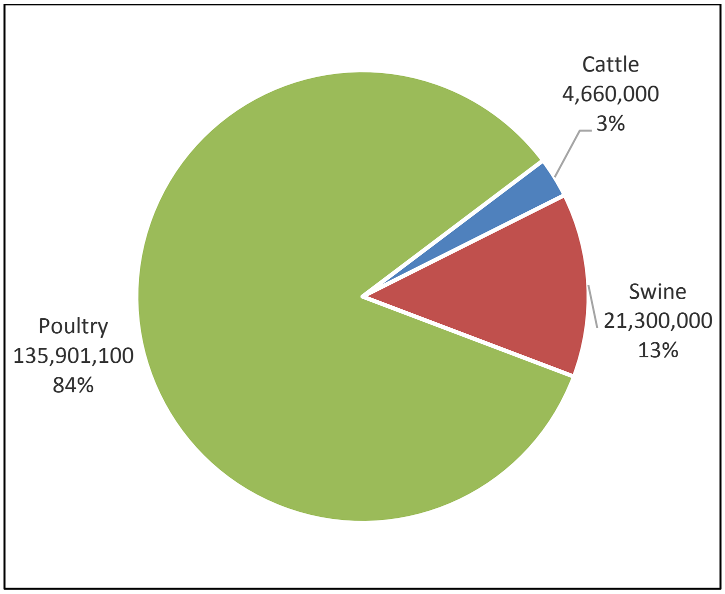
Enteric Fermentation

CH_4 emissions from enteric fermentation were 7.02 $MMtCO_2e$ in 2015, increasing 2.41% from 2014. This can be attributed to a 1.79% increase in the total cattle population and a 5.45% increase in the total swine population. While poultry and swine make up the greatest percentages of total livestock in Iowa as shown in Figure 4, enteric fermentation emissions are primarily driven by the cattle population. This is because cattle emit more CH_4 than other ruminant animals due to their unique stomachs. In addition, poultry do not emit methane through enteric fermentation. The amount of methane emitted from each animal type is shown in Table 9.

Table 9: Methane Emitted per Animal

Animal Type	kg/head CH_4 Emitted (ICF 2016a)
Beef Cattle	42.0 – 95.1
Dairy Cattle	43.5 – 132.4
Goats	5.0
Horses	18.0
Sheep	8.0
Swine	1.5

Figure 4: 2015 Animal Populations (USDA 2014a, 2015)[6]



Manure Management

Factors influencing CH_4 and N_2O emissions include the animal type, animal population, animal mass, the type of manure management system, etc. GHG emissions from manure management increased 3.39% from 2015 and accounted for 23.51% of agricultural GHG emissions in 2015. The increase in emissions in 2015 can be linked to increases of 90,000 head of cattle, 1,100,000 swine, and 20,000 sheep (USDA 2015). As mentioned earlier, the poultry population was assumed to be the same as 2012.

Agricultural Soils

N_2O emissions from agricultural soils increased 2.48% from the previous year. At the same time, field crop production (corn, oats, soybeans, and wheat) increased 6.07% from 2014-2015 and alfalfa production increased 2.98% as shown in Table 10.

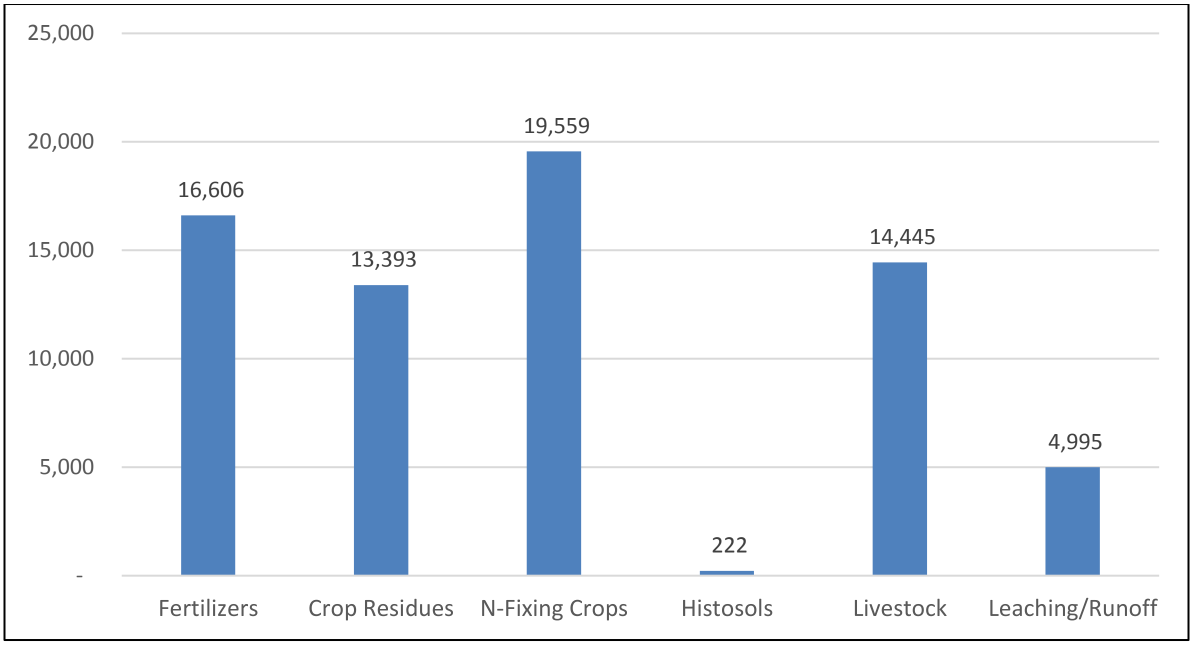
Table 10: Iowa Crop Production 2014 – 2015 (USDA 2016b)

Crop	**2014 (1000 Bushels)**	**2015 (1000 Bushels)**
Barley	85	85
Corn for Grain	2,367,400	2,505,600
Oats	3,520	4,161
Rye	46	46
Sorghum for Grain	59	59
Soybeans	498,270	533,700
Wheat	735	780
Total	**2,870,114**	**3,044,430**
Crop	**2014 (1000 tons)**	**2015 (1000 tons)**
Alfalfa	2,916	3,003

[6] The goat, horse, and sheep population each account for less than 1% of the total animal population.

N_2O emissions from agricultural soils accounted for 57.64% of all agricultural GHG emissions and 16.63% of total statewide GHG emissions in 2015. The majority of GHG emissions from agricultural soils can be attributed to crop production (fertilizers, crop residues, and nitrogen fixing) as shown in Figure 5.

Figure 5: 2015 Gross GHG Emissions from Agricultural Soils (metric tons N_2O)



Uncertainty

Excerpted from SIT Agriculture Module (ICF 2016a):

Enteric Fermentation

The quantity of methane (CH_4) emitted from enteric fermentation from livestock is dependent on the estimates of animal populations and the emission factors used for each animal type. Therefore, the uncertainty associated with the emission estimate stems from those two variables. Uncertainty is also introduced as animal populations vary throughout the year. There is also uncertainty associated with the original population survey methods used by USDA. Emission factors vary in each animal, depending on its production and diet characteristics, as well as genetics (ICF 2016a).

Manure Management

As with enteric fermentation, uncertainty occurs in animal populations and the emission factors used for each animal. However, the largest contributor to uncertainty in manure management emissions in the SIT is the lack of Iowa-specific data describing manure management systems and the CH_4 and N_2O emission factors used for these systems. In addition, there is uncertainty in the maximum CH_4 producing potential (B_0) used for each animal group. This value varies with both animal and diet characteristics, so estimating an average across an entire population introduces uncertainty. While the B_0 values used in the SIT vary by animal subcategory to attempt to represent as many of these differences as possible, there is not sufficient data available at this time to estimate precise values that accurately portray the B_0 for all animal types and feeding circumstances (ICF 2004).

Agricultural Soils

The amount of N_2O emission from managed soils is dependent on a large number of variables other than N inputs. They include soil moisture, pH, soil temperature, organic carbon availability, oxygen partial pressure, and soil amendment practices. The effect of the combined interaction of these variables on N_2O flux is complex and highly uncertain. The methodology used in the SIT is based only on N inputs, does not include other variables, and treats all soils, except histosols, equally. In addition, there is limited knowledge regarding N_2O productions from soils when N is added to soils. It is not possible to develop emission factors for all possible combinations of soil, climate, and management conditions.

Uncertainties also exist in fertilizer usage calculations. The fertilizer usage does not include non-commercial fertilizers other than manure and crop residues, and site-specific conditions are not considered in determining the amount of N excreted from animals. Additional uncertainty occurs due to lack of Iowa-specific data for application of sewage sludge and cultivation of histosols (ICF 2016a).

Uncertainties in the estimation method for agricultural residue burning are noted above under the “Methods” heading.

Chapter 3 – Fossil Fuel Consumption

This chapter includes GHG emissions from fossil fuel consumption in four categories: electric generation, residential, industrial, and commercial. The residential, industrial, and commercial categories are often combined into one category called RCI. Together, these four categories accounted for 46.82% of Iowa's total 2015 GHG emissions. Fossil fuels combusted by mobile sources are included in the transportation sector and discussed later in this report in *Chapter 6 – Transportation*. Emissions from the electric generation category include direct emissions resulting from the combustion of fossil fuels at the electric generating station (i.e. power plant). Indirect emissions from electricity consumed at the point of use (i.e. residential electric water heaters) are discussed in *Chapter 10 – Indirect Emissions from Electricity Consumption*.

Method

Residential, Commercial, Industrial (RCI)

GHG emissions were calculated using two SIT modules – the CO_2FFC module for carbon dioxide (CO_2) emissions and the Stationary Combustion module for CH_4 and N_2O emissions (ICF 2016a-d). These modules calculate energy emissions based on annual statewide consumption for the sectors and fuels listed in Table 11:

Table 11: Fuel Types Included in Fossil Fuel Consumption

Fuel Types	Residential	Commercial	Industrial
Asphalt/Road oil			x
Aviation gasoline blending components			x
Coal	x	x	x
Coking coal, other coal			x
Crude oil			x
Distillate fuel oil	x	x	x
Feedstocks			x
Kerosene	x	x	x
LPG	x	x	x
Lubricants			x
Misc. petroleum products			x
Motor gasoline		x	x
Motor gasoline blending components			x
Natural gas	x	x	x
Pentanes plus			x
Petroleum coke			x
Residual fuel		x	x
Still gas			x
Special naphthas			x
Unfinished oils			x
Waxes			x
Wood	x	x	x

Iowa-specific 2015 energy consumption data will not be published by the U.S. Energy Information Administration until June 2017, so the DNR projected 2015 energy consumption. This was done by using the EIA's *Annual Energy Outlook (AEO) 2016 with Projections to 2040* (EIA 2016a) and 2014 bulk energy consumption data from the EIA's State Energy Data System (SEDS) (EIA 2016b). The AEO2016 includes several different projection cases, which each address different uncertainties. The DNR used the AEO2016 "Reference Case", which represents federal and state legislation and final implementation of regulations as of the end of February 2016. The projections in the Reference Case are done at the regional level, and Iowa is in the West North Central U.S. Census Region. The 2015 energy consumption was estimated for each fuel type using one of three methods as described below and shown in Table 12:

<u>Fuel Method 1</u>
The percent change in the regional consumption of each fuel type in the AEO2016 was calculated. The percent change was then applied to the Iowa 2014 fuel consumption in SEDS. This method was used for the fuel types listed in Table 12. This method is different from previous years where the ratio of Iowa fuel consumption from SEDS to the regional fuel consumption for the previous year in the AEO was calculated and then applied to the predicted regional fuel consumption for the current year in the AEO.

<u>Fuel Method 2</u>
These sectors were not included in the AEO Reference Case, so it was assumed that 2015 fuel consumption was equal to the 2014 fuel consumption. This method was used for the fuel types listed in Table 12 below.

Table 12: Method Used to Estimate 2015 Fuel Consumption

Fuel Type	Estimation Method
Commercial Distillate Fuel Oil	Method 1
Commercial Kerosene	Method 1
Commercial LPG	Method 1
Commercial Motor Gasoline	Method 1
Commercial Natural Gas	Method 1
Commercial Residual Fuel	Method 1
Industrial Coal	Method 1
Industrial Distillate Fuel Oil	Method 1
Industrial LPG	Method 1
Industrial Motor Gasoline	Method 1
Industrial Natural Gas	Method 1
Industrial Other Coal	Method 1
Industrial Residual Fuel	Method 1
Residential Distillate Fuel	Method 1
Residential Kerosene	Method 1
Residential LPG	Method 1
Residential Natural Gas	Method 1
Commercial Coal	Method 2
Commercial Wood	Method 2

Table 12 (continued)

Fuel Type	Estimation Method
Industrial Asphalt and Road Oil	Method 2
Industrial Aviation Gasoline Blending Components	Method 2
Industrial Coking Coal	Method 2
Industrial Crude Oil	Method 2
Industrial Feedstocks, Naphtha less than 401 F	Method 2
Industrial Feedstocks, Other Oils greater than 401 F	Method 2
Industrial Kerosene	Method 2
Industrial Lubricants	Method 2
Industrial Misc. Petro Products	Method 2
Industrial Motor Gasoline Blending Components	Method 2
Industrial Pentanes Plus	Method 2
Industrial Petroleum Coke	Method 2
Industrial Special Naphthas	Method 2
Industrial Still Gas	Method 2
Industrial Unfinished Oils	Method 2
Industrial Waxes	Method 2
Industrial Wood	Method 2
Residential Coal	Method 2
Residential Wood	Method 2

Electric Generating Facilities

Emissions from the electric generating facilities were not calculated using fuel consumption data. Instead, the total reported CO_2, CH_4, and N_2O emissions from the federal GHG reporting program (40 CFR 98, EPA 2016) were used. This data is more accurate than the values from EIA because the CO_2 emissions reported by facilities to EPA are actual measured emissions values from continuous emission monitors (CEMS) located on electric generating units, and the CH_4 and N_2O emissions are calculated using facility-specific fuel heating values. The CO_2 data reported to the federal GHG reporting program was consistent with the CO_2 emissions reported by the same facilities to EPA as required by the Acid Rain Program (CAMD 2016).

<u>Adjustments</u>

The DNR previously forecasted 2014 emissions from RCI due to a lack of Iowa-specific bulk energy consumption data. However, the 2014 energy data was released by EIA in June 2016 (EIA 2016b), so the DNR used the data to recalculate 2014 emissions as shown in Table 13.

Table 13: Recalculated Fossil Fuel Emissions (MMtCO_2e)

Category	2014 Value Published Dec. 2015	2014 Updated Value
Residential	5.36	5.37
Commercial	5.10	4.91
Industrial	22.98	22.53
Electric Power	33.44	33.44
Total	**66.88**	**66.25**

Results

Total GHG emissions from fossil fuel consumption in 2015 were 60.42 MMtCO_2e, a decrease of 8.80% from 2014 and 0.80% from 2005 levels as shown in Table 14 below and Figure 6 on the next page. Emissions from each of the four fossil fuel categories decreased in 2015 due to decreases in fossil fuel consumption:

- residential fuel use emissions decreased 20.24%
- commercial fuel use emissions decreased 10.01%
- industrial fuel use emissions decreased 1.22%
- electric generating facility fuel use emissions decreased 11.89%

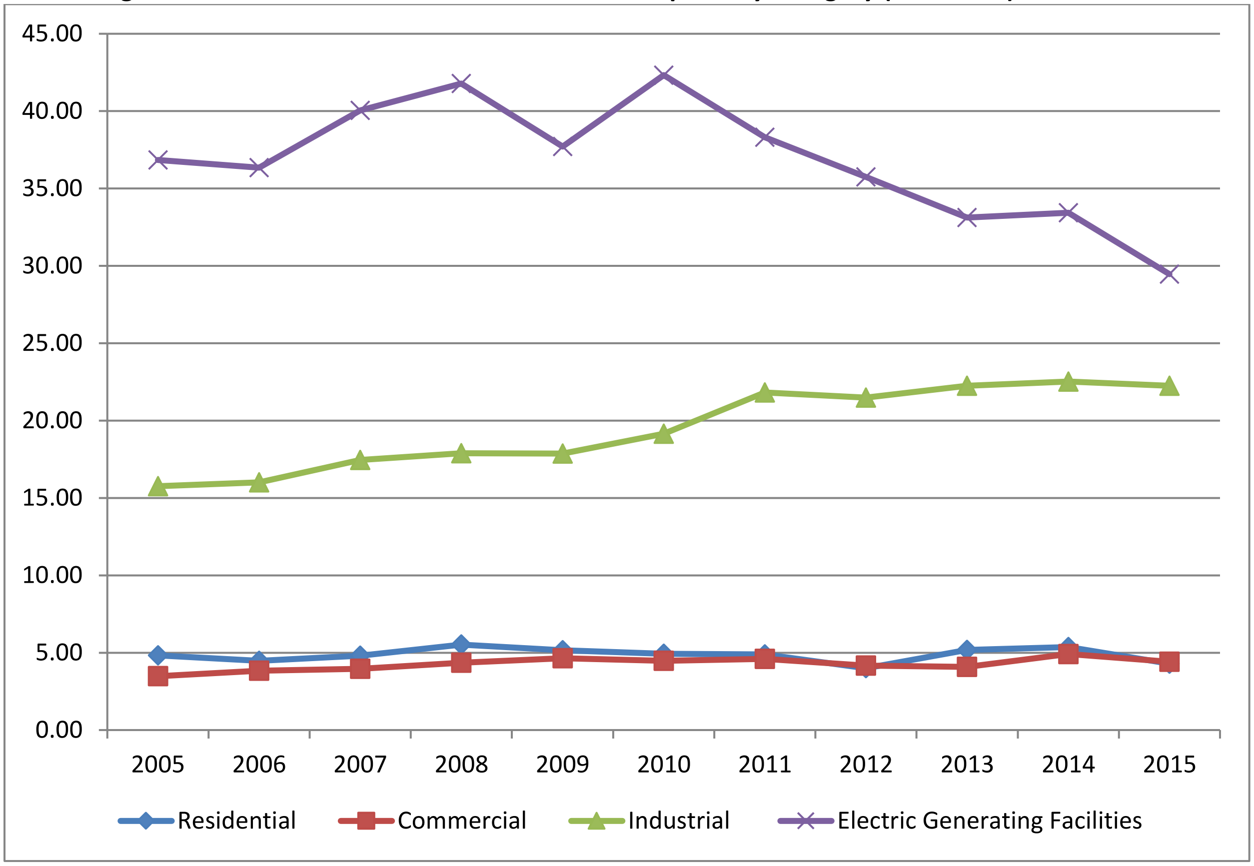
While the electric generating facilities category had the highest emissions of the four fossil fuel categories, for the first time it accounted for less than 50% of the emissions from the fossil fuel combustion sector, accounting for 48.77%. Emissions from this category were also 30.39% lower than their peak in 2010 as shown in Table 14.

Table 14: GHG Emissions from Fossil Fuel Consumption by Category (MMtCO_2e)[7]

Category/Fuel Type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Residential	4.82	4.48	4.81	5.52	5.16	4.94	4.89	4.00	5.17	5.37	4.28
Commercial	3.48	3.84	3.95	4.35	4.64	4.47	4.60	4.16	4.08	4.91	4.42
Industrial	15.76	16.00	17.45	17.88	17.86	19.15	21.82	21.49	22.25	22.53	22.25
Electric Generating Facilities	36.84	36.35	40.04	41.78	37.71	42.33	38.98	35.76	33.12	33.44	29.46
Total	**60.90**	**60.68**	**66.26**	**69.53**	**65.38**	**70.89**	**70.29**	**65.40**	**64.62**	**66.25**	**60.42**

[7] Values do not include emissions from the transportation sector. Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 6: GHG Emissions from Fossil Fuel Consumption by Category ($MMtCO_2e$)



Uncertainty -

CO_2 Emissions - Excerpted from SIT CO_2FFC Module (ICF 2016a):

The amount of CO_2 emitted from energy consumption depends on the type and amount of fuel that is consumed, the carbon content of the fuel, and the fraction of the fuel that is oxidized. Therefore, the more accurate these parameters are, the more accurate the estimate of direct CO_2 emissions will be. Nevertheless, there are uncertainties associated with each of these parameters.

National total energy consumption data is fairly accurate, but there is more uncertainty in the state-level data, especially when allocating consumption to the individual end-use sectors (i.e. residential, commercial, and industrial). The amount or rate at which carbon is emitted to the atmosphere can vary greatly depending on the fuel and use, and may vary at the state-level compared to the national default levels in the SIT.

The uncertainty in carbon content and oxidation are much lower than with fuel consumption data. Carbon contents of each fuel type are determined by EIA by sampling and the assessment of market requirements, and, with the exception of coal, do not vary significantly from state to state. EIA takes into account the variability of carbon contents of coal by state; these coefficients are also provided in the SIT.

Uncertainty is also introduced by the complexity in calculating emissions from the import/export of electricity. The precise fuel mix used to generate the power crossing state lines is very difficult to determine, so, an average fuel mix for all electricity generation within a specific region of the grid must usually be used. Moreover, these emissions factors are generated by emission monitors (rather than carbon contents of fuels), which may overestimate CO_2 emissions to a small extent (ICF 2016a).

CH_4 and N_2O Emissions - Excerpted from SIT Stationary Combustion Module (ICF 2016b):
The amount of CH_4 and N_2O emitted depends on the amount and type of fuel used, the type of technology in which it is combusted (e.g., boilers, water heaters, furnaces), and the type of emission control used. In general, the more detailed information available on the combustion activity, the lower the uncertainty. However, as noted in the Revised 1996 IPCC Guidelines (IPCC/UNEP/OECD/IEA 1997), the contribution of CH_4 and N_2O to overall emissions is small and the estimates are highly uncertain.

Uncertainties also exist in both the emission factors and the EIA energy consumption data used to calculate emissions. For example, the EIA state data sets do not fully capture the wood used in fireplaces, wood stoves, and campfires. As with CO_2, uncertainty is also introduced with allocating energy consumption data to the individual end-use sectors and estimation of the fraction of fuels used for non-energy (ICF 2016b).

Chapter 4 - Industrial Processes

This chapter includes non-combustion GHG emissions from a variety of industrial processes. The processes and GHG pollutants emitted from each category are shown in Table 15. Emissions from these industries do not include emissions from fossil fuel combustion, which are included in *Chapter 3 – Fossil Fuel Combustion.*

Table 15: Industrial Processes and GHG Emissions

Category	GHGs Emitted
Cement Production	CO_2
Lime Manufacture	CO_2
Limestone and Dolomite Use	CO_2
Soda Ash Use	CO_2
Iron and Steel Production	CO_2
Ammonia Production & Urea Consumption	CO_2
Nitric Acid Production	N_2O
Ozone Depleting Substances (ODS) Substitutes	HFCs, PFCs, and SF_6
Electric Power Transmission and Distribution	SF_6

Cement Production

Carbon Dioxide (CO_2) is emitted during a process called calcining when limestone is heated in a cement kiln to form lime and CO_2. The CO_2 is vented to the atmosphere and the lime is then mixed with silica-containing materials such as clay to form clinker, an intermediate product that is made into finished Portland cement (ICF 2004). Two facilities in Iowa currently produce Portland cement.

Lime Manufacture

Similar to cement manufacturing, lime is produced by heating limestone in a kiln, creating lime and CO_2. The CO_2 is typically released to the atmosphere, leaving behind a product known as quicklime, which can then be used to produce other types of lime (ICF 2004). One facility currently manufactures lime in Iowa.

Limestone and Dolomite Use

Limestone and dolomite are used in industrial processes such as glass making, flue gas desulfurization, acid neutralization, etc.

Soda Ash Use

Soda ash is currently only produced in three states – Wyoming, Colorado, and California. However, commercial soda ash is used as a raw material in a variety of industrial processes and in many familiar consumer products such as glass, soap, and detergents (ICF 2016b). In Iowa it is commonly used by corn wet millers for pH control, in ion exchange regeneration, and in other operations (DNR 2010).

Iron and Steel

Iron and steel production is an energy-intensive process that also generates process-related GHG emissions. Steel is produced from pig iron or scrap steel in a variety of specialized steel-making furnaces, including electric arc furnaces (EAFs) and basic oxygen furnaces (BOFs) (EPA 2010). There are currently no pig iron mills operating in Iowa. All three steel production facilities currently operating in Iowa use EAFs to produce steel from scrap. These furnaces use carbon electrodes, coal, natural gas, and other substances such as limestone and dolomite to aid in melting scrap and other metals, which are then improved to create the preferred grade of steel. In EAFs, CO_2 emissions result primarily from the consumption of carbon electrodes and also from the consumption of supplemental materials used to augment the melting process (EPA 2010).

Ammonia Production and Urea Consumption

CO_2 is released during the manufacture of ammonia. The chemical equations to calculate the release of CO_2 are fairly complicated, but in general, anhydrous ammonia is synthesized by reacting nitrogen with hydrogen. The hydrogen is typically acquired from natural gas. The majority of direct CO_2 emissions occur when the carbon in the natural gas is then eliminated from the process by converting it to CO_2. Other emissions of CO_2 can occur during condensate stripping or regeneration of the scrubbing solution. CO_2 emissions may also be captured for use in urea synthesis or carbon sequestration and storage (WRI 2008). Three facilities in Iowa currently produce ammonia.

Nitric Acid Production

Nitrous Oxide (N_2O) is produced when ammonia is oxidized to produce nitric acid. Two facilities in Iowa currently produce nitric acid.

Consumption of ODS Substitutes

Ozone Depleting Substances (ODS) are often used in refrigeration, air conditioning, aerosols, solvent cleaning, fire extinguishers, etc. However, ODS are being phased out per the Montreal Protocol and the 1990 Clean Air Act Amendments. The most common ODS are HFCs, but PFCs and SF_6 may also be used (ICF 2016b).

Electric Power Transmission and Distribution

SF_6 is used as an insulator in electricity transmission and distribution in equipment such as transformers, high-voltage circuit breakers, substations, and transmission lines (ICF 2016b).

Other Industry Types

GHG emissions from soda ash manufacturing, adipic acid production, (primary) aluminum production, HCFC-22 production, semiconductor manufacturing, and magnesium production and processing were not calculated as the DNR is not aware of any of these facilities currently operating in Iowa.

Method

2015 emissions from industrial processes were calculated using either the SIT (ICF 2016a) or using GHG emissions reported to EPA by individual facilities to the federal GHG reporting program (40 CFR 98, EPA 2016a) as shown in Table 16.

Table 16: Industrial Processes Calculation Methods and Activity Data

Category	Year	Calculation Method	Data Source
Ammonia and Urea Production	2015	40 CFR 98 Subpart G	(EPA 2016a)
Cement Production		40 CFR 98 Subpart H	(EPA 2016a)
Iron and Steel Production		40 CFR 98 Subpart Q	(EPA 2016a)
Lime Manufacture		40 CFR 98 Subpart S	(EPA 2016a)
Nitric Acid Production		40 CFR 98 Subpart V	(EPA 2016a)
Electric Power Transmission and Distribution	2014 as proxy for 2015	SIT	(EIA 2016), (EPA 2016b)
Limestone and Dolomite Use		SIT	(USGS 2016a)
ODS Substitutes		SIT	SIT default value
Soda Ash Use	2015	SIT	(USGS 2016b)

Categories Calculated using the SIT

Emissions from use of limestone and dolomite in industrial processes were calculated by multiplying Iowa's annual consumption by the ratio of national consumption for industrial uses to total national consumption.

Emissions from ODS substitutes and soda ash consumption categories were calculated by assuming that Iowa emissions were 0.97% of national emissions because Iowa's population is 0.97% of the total U.S. Population (U.S. Census 2016).

Emissions from electric power transmission distribution were calculated by determining the ratio between 2014 Iowa retail sales vs. 2014 national retail sales (EIA 2016), and applying that ratio to 2014 national emissions of sulfur hexafluoride (SF_6). 2014 was used as a proxy for 2015.

Adjustments

2014 emissions were recalculated for three sectors – nitric acid production; cement manufacture; limestone and dolomite use; and ODS substitutes – as shown in Table 17.

Nitric Acid Production

2014 emissions from the production of nitric acid were updated to correct a math error.

Limestone and Dolomite Use

2014 emissions from use of limestone and dolomite were recalculated using 2014 data from Tables 6 and 10 of the Mineral Yearbook (USGS 2016a). In the previous inventory, 2013 data was used as a proxy for 2014.

Substitutes for Ozone Depleting Substances (ODS)

2014 emissions were recalculated using 2014 national emissions (EPA 2016b), adjusted for Iowa population (U.S. Census 2016). In the previous inventory, 2013 data was used as a proxy for 2014.

Table 17: Recalculated Emissions from Industrial Processes (MMtCO$_2$e)

Sector	2014 Value Published Dec. 2015	2014 Updated Value
Nitric Acid Production	0.86	0.69
Limestone and Dolomite Use	0.33	0.21
ODS Substitutes	1.33	1.34

Results

GHG emissions from industrial processes in 2015 were 5.01 MMtCO$_2$e, or 3.88% of total statewide GHG emissions. Emissions from this sector increased 2.00% from 2014 as shown in Table 18. Ammonia and urea production, ODS substitutes, nitric acid production, and cement manufacture were the highest contributors to industrial process emissions in 2015 as shown in Figure 7 on the next page.

Table 18: GHG Emissions from Industrial Processes (MMtCO$_2$e)[8]

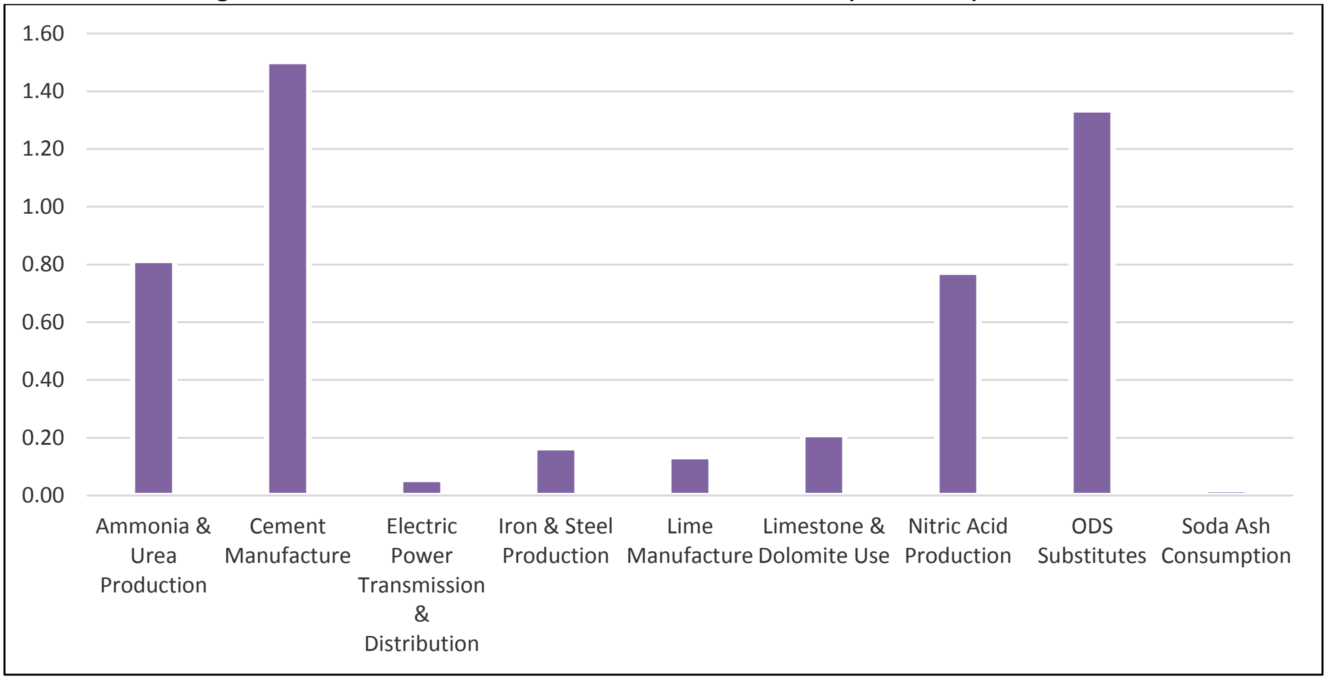
Category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Ammonia & Urea[9]	1.01	0.91	0.95	0.87	0.60	0.84	0.75	0.85	0.88	0.86	0.81
Cement Manufacture	1.27	1.29	1.27	1.31	0.84	0.72	0.79[10]	1.27	1.41	1.38	1.50
Electric Power T&D	0.12	0.12	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.06	0.06
Iron & Steel Production	0.13	0.13	0.13	0.12	0.09	0.23	0.20	0.23	0.19	0.18	0.16
Lime Manufacture	0.18	0.17	0.16	0.17	0.13	0.18	0.18	0.18	0.16	0.17	0.13
Limestone & Dolomite Use	0.18	0.29	0.24	0.25	0.29	0.39	0.16	0.15	0.33	**0.21**	0.21
Nitric Acid Production	0.68	0.75	0.81	0.90	0.90	0.99	0.94	0.99	0.83	**0.69**	0.77
ODS Substitutes	0.99	1.01	1.01	1.20	1.27	1.36	1.39	1.44	1.33	**1.34**	1.34
Soda Ash Consumption	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	**4.58**	**4.71**	**4.70**	**4.93**	**4.23**	**4.80**	**4.49**	**5.18**	**5.20**	**4.91**	**5.01**

[8] Totals may not equal the sum of subtotals shown in this table due to independent rounding.

[9] 2005 – 2007 values may be overestimates as they do not account for CO$_2$ that was recovered for urea or carbon sequestration and storage.

[10] Total includes emissions from fossil fuel combustion that were measured by the Continuous Emission Monitor on the kiln(s). This may be double-counted in the Fossil Fuel Combustion sector.

Figure 7: 2015 GHG Emissions from Industrial Processes ($MMtCO_2e$)



<u>Uncertainty</u>

Uncertainty occurs in categories where SIT default activity data was used instead of Iowa-specific activity data, such as limestone and dolomite use, soda ash use, ODS substitutes, and electric power transmission and distribution.

Other major sources of uncertainty associated with calculating emissions from industrial processes are listed below (*Excerpted from SIT Industrial Processes Module (ICF 2016a).*

- The estimation of emissions for limestone and dolomite use contains some inherent uncertainty based on limestone's variable composition.
- Although the model used to generate national emission estimates from the consumption of ozone depleting substances substitutes is comprehensive, significant uncertainties exist and are exacerbated by the use of population to disaggregate national emissions.
- Uncertainties in emission estimates for electric power transmissions and distribution can be attributed to apportioning national emissions based on electricity sales because this method incorporates a low probability assumption that various industry emission reduction practices occur evenly throughout the country.

Chapter 5 - Natural Gas Transmission & Distribution

This chapter includes GHG emissions from natural gas transmission and distribution (T & D) in Iowa. In this sector, methane (CH_4) is emitted from leaks, vents, regulators, valves, compressors, accidents, and other devices located along the natural gas transmission and distribution networks. Carbon dioxide (CO_2) may also be emitted from venting and flaring, but was not calculated due to lack of data. GHG emissions from coal mining, natural gas production, oil production, oil transmission, and oil transportation are not included as those industries are currently not active in Iowa.

Method

Natural Gas Transmission

Natural gas is transmitted in Iowa through large, high-pressure lines. These lines transport natural gas from production fields and processing plants located out-of-state to Iowa storage facilities, then to local distribution companies (LDCs) and high volume customers. Compressor stations, metering stations, and maintenance facilities are located along the transmission system. CH_4 is emitted from leaks, compressors, vents, and pneumatic devices (ICF 2016b).

The number of miles of transmission pipeline in Iowa was obtained from the United States Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration's (PHMSA) Office of Pipeline Safety (DOT 2016). The Iowa Utilities Board confirmed that the number of natural gas compressor and gas storage stations did not change from the previous year (Stursma 2016).

Natural Gas Distribution

Natural gas is distributed through large networks of small, low-pressure pipelines. Natural gas flows from the transmission system to the distribution network at municipal gate stations, where the pressure is reduced for distribution within municipalities. CH_4 is emitted from leaks, meters, regulators, and accidents (ICF 2016b). Activity data from the DOT PHSMA's Office of Pipeline Safety was used for calculating emissions (DOT 2016). Data entered included miles of steel and cast iron distribution pipeline, unprotected and protected; number of services; and number of steel services, unprotected and protected.

Natural Gas Venting and Flaring

The DNR is unable to find data on the annual amount of natural gas vented and flared from natural gas transmission pipelines. This data is not tracked by the EIA (Little 2011), and the DNR has previously requested, but not received, this information from the Federal Energy Regulatory Agency (FERC). Therefore, no GHG emissions were calculated from natural gas venting and flaring.

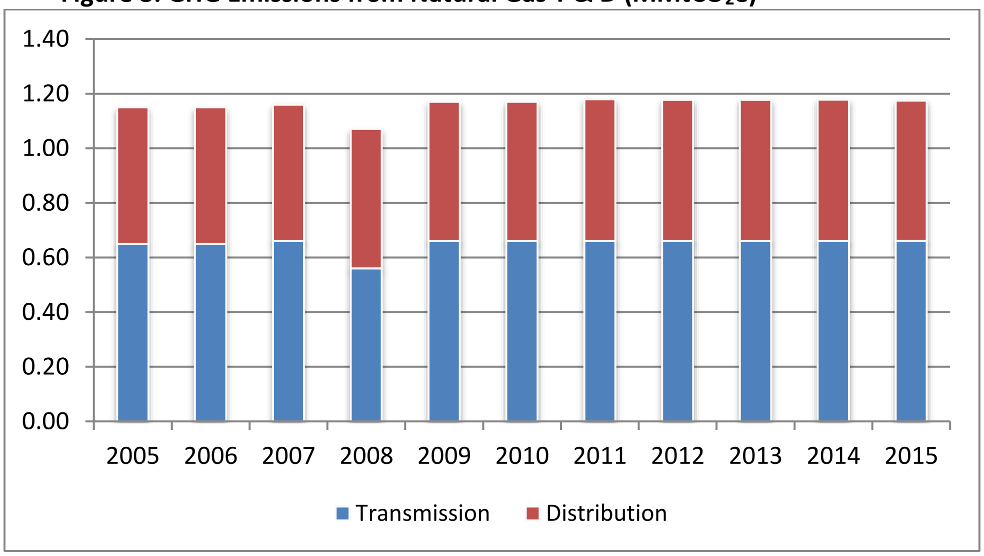
Results

Total GHG emissions from natural gas transmission and distribution were 1.1748 $MMtCO_2e$[11] in 2015, a decrease of 0.32% from 2014 and an increase of 2.23% from 2005 as shown in Table 19 and Figure 8. Emissions decreased in 2015 due to decreases in the number of steel services (e.g. gas meters). GHG emissions from this sector account for 0.91% of 2015 statewide GHG emissions.

Table 19: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)

Category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Transmission	0.6474	0.6487	0.6589	0.6600	0.6609	0.6611	0.6601	0.6604	0.6606	0.6605	0.6609
Distribution	0.5018	0.5026	0.5046	0.5120	0.5110	0.5066	0.5151	0.5173	0.5154	0.5181	0.5139
Total	**1.1492**	**1.1513**	**1.1635**	**1.1720**	**1.1720**	**1.1677**	**1.1752**	**1.1777**	**1.1760**	**1.1786**	**1.1748**

Figure 8: GHG Emissions from Natural Gas T & D ($MMtCO_2e$)



Uncertainty

Excerpted from SIT Natural Gas and Oil Systems Module (ICF 2016a):

The main source of uncertainty in the SIT calculation methods is the emission factors. The emission factors used are based on a combination of statistical reporting, equipment design data, engineering calculations and studies, surveys of affected facilities and measurements. In the process of combining these individual components, the uncertainty of each individual component is pooled to generate a larger uncertainty for the overall emission factor. In addition, statistical uncertainties arise from natural variation in measurements, equipment types, operational variability, and survey and statistical methodologies. The method also does not account for regional differences in natural gas infrastructure and activity levels (ICF 2016a).

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[11] DNR uses two decimal places throughout this report for consistency. However, in this sector four decimal places are needed show the difference in emissions from year to year.

Chapter 6 - Transportation

This chapter includes GHG emissions from both highway and non-highway vehicles such as aviation, boats, locomotives, tractors, other utility vehicles, and alternative fuel vehicles.

Method

In previous years, emissions were calculated using two SIT modules – the CO_2FFC module for CO_2 emissions and the Mobile Combustion module for CH_4 and N_2O emissions. The CO_2FFC module calculates CO_2 emissions from all vehicle categories based on fossil fuel consumption, while the Mobile Combustion module calculates methane (CH_4) and nitrous oxide (N_2O) emissions from non-highway vehicles based on fossil fuel consumption and CH_4 and N_2O emissions from highway vehicles based on vehicle miles traveled (VMT).

This year, the DNR was able to calculate CO_2 emissions using just the Mobile Combustion module (ICF 2016a), which has been updated by EPA to calculate CO_2, CH_4, and N_2O emissions from highway vehicles based on vehicle miles traveled. This is a more accurate method as it accounts for the vehicle type and vehicle age in the calculation, as well as accounting for the annual vehicle miles traveled. Emissions from non-highway vehicles are still calculated based on fossil fuel consumption.

Highway Vehicles (CH_4 and N_2O)

Highway vehicles include passenger cars, truck, motorcycles, and heavy-duty vehicles. CH_4 and N_2O emissions from highway vehicles were calculated using the SIT as follows:

1. The vehicle miles traveled (VMT) for each vehicle type was calculated using the total annual VMT of 33,109 million miles (IDOT 2016). Neither the IDOT nor FHWA track state-level VMT by the seven classes used in the SIT, so the VMT was distributed among seven vehicle/fuel classes using the national distribution percentages from the Tables A-95 and A-96 from Annex 3 of the most recent national GHG inventory, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014* (EPA 2016). The classes and the national distribution percentages are shown in Table 20.

Table 20: VMT Vehicle/Fuel Classes and Distribution

Vehicle Class	Acronym	2014 (EPA 2016)	2014 Iowa VMT (10^6 miles)
Heavy duty diesel vehicle	HDDV	8.30%	2,749
Heavy duty gas vehicle	HDGV	1.05%	346
Light duty diesel truck	LDDT	0.78%	259
Light duty diesel vehicle	LDDV	0.33%	111
Light duty gasoline truck	LDGT	19.40%	6,423
Light duty gasoline vehicle	LDGV	69.41%	22,982
Motorcycle	MC	0.72%	239
Total		**100.00%**	**33,109**

2. The VMT was then converted for use with existing emission factors. Iowa-specific emission factors were not available, so the SIT default emission factors were used. These factors are consistent with those used in the most recent national GHG inventory.
3. Next the VMT was allocated by model year. Iowa-specific VMT data by model year was not available, so the VMT was allocated using the default national on-road age distribution by vehicle/fuel type in the SIT. The “Annual Vehicle Mileage Accumulation” table in SIT was updated to match that in Table A-99 in the most recent national inventory (EPA 2016).
4. The control technology was then allocated by model year. Iowa-specific control technologies by model year were not available, so the national control technology values were used. The values in the SIT matched the Tables A-103, A-104, and A-105 in Annex 3 of the most recent national inventory (EPA 2016). 100% was used for Tier 2 vehicles for 2013, 2014, and 2015.

Non-highway Vehicles (CH_4 and N_2O)

Non-highway vehicles include aviation, marine vessels, locomotives, and tractors. In general, CH_4 and N_2O emissions from non-highway vehicles were calculated using data from either the Energy Information Administration (EIA) or Federal Highway Administration as shown in Table 21.

Table 21: Iowa-specific Non-highway Activity Data Used

<table>
<tr><th>Vehicle Type</th><th>Fuel Type</th><th>Year</th><th>Data Source</th></tr>
<tr><td>Aviation</td><td>Gasoline</td><td rowspan="2">2014 used as proxy for 2015</td><td rowspan="2">EIA SEDS (EIA 2016b)</td></tr>
<tr><td>Aviation</td><td>Jet Fuel, Kerosene</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Boats</td><td rowspan="4">Gasoline</td><td rowspan="4">2014 used as proxy for 2015</td><td rowspan="4">FHWA 2016</td></tr>
<tr><td>Heavy Duty Utility</td></tr>
<tr><td>Tractors</td></tr>
<tr><td>Construction</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Locomotives</td><td rowspan="2">Distillate Fuel</td><td rowspan="2">2014 used as proxy for 2015</td><td rowspan="2">EIA Adjusted Sales (EIA 2016a)</td></tr>
<tr><td>Tractors</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Construction</td><td>Distillate Fuel</td><td rowspan="4">2013 used as proxy for 2014-2015</td><td rowspan="4">SIT default value</td></tr>
<tr><td>Heavy Duty</td><td>Distillate Fuel</td></tr>
<tr><td>Small Utility</td><td>Gasoline</td></tr>
<tr><td colspan="2">Alternative Fuel Vehicles</td></tr>
</table>

<u>Adjustments</u>

2014 emissions have been updated since the DNR’s 2014 GHG Inventory Report was published in December 2015. The DNR previously forecasted 2014 emissions for some fuel types due to a lack of Iowa-specific bulk energy consumption data. However, the 2014 energy data was released by EIA in June 2016 (EIA 2016b), so the DNR used the data to recalculate 2014 emissions as shown in Table 22.

Table 22: Recalculated CH_4 and N_2O Emissions from Transportation ($MMtCO_2e$)

Pollutant	2014 Value Published Dec. 2015	2014 Updated Value
CH_4	0.0301[12]	0.0295
N_2O	0.20	0.22

In addition, CO_2 emissions from 2011 – 2014 were recalculated using the Mobile Combustion SIT module based on vehicle miles traveled for highway vehicles as shown in Table 23. 2014 CO_2 emissions were also recalculated using the most recent 2014 fuel consumption data available. Last year, 2013 fuel consumption was used as a proxy for 2014 for some non-highway vehicle types.

Table 23: Recalculated CO_2 Emissions from Transportation ($MMtCO_2e$)

Pollutant	Year	Value Published Dec. 2015	Updated Value
CO_2	2011	22.37	19.26
	2012	20.79	19.30
	2013	21.42	19.25
	2014	22.07	19.63

Results

Total GHG emissions from transportation were 20.22 $MMtCO_2e$ in 2015 as shown in Table 24 below. This was an increase of 1.72% from 2014. Emissions from 2011 – 2015 cannot be directly compared to prior years because of the change in the CO_2 calculation method starting with 2011. GHG emissions from this sector account for 15.67% of 2015 statewide GHG emissions. CO_2 is the most prevalent GHG, accounting for 98.87% of GHG emissions from the transportation sector.

Table 24: GHG Emissions from Transportation ($MMtCO_2e$)[13]

Pollutant	2011	2012	2013	2014	2015
CO_2	19.26	19.30	19.25	19.63	19.99
CH_4	0.03	0.03	0.03	0.03	0.03
N_2O	0.28	0.25	0.22	0.22	0.20
Total	**19.53**	**19.57**	**19.50**	**19.88**	**20.22**

The majority of emissions (56.68%) are from gasoline highway vehicles as shown in Figure 9. The SIT shows that while CO_2 emissions vary from year to year, emissions of CH_4 and N_2O have steadily decreased as shown in Figure 10, Table 24, and Table 25. Nationally, CH_4 emissions declined by 64% and N_2O emissions decreased 60% from 1990 - 2014, due mainly to the addition of control technologies in on-road vehicles for CH_4 since the mid-1990s and improvements in N_2O control technologies since 1997 (EPA 2016).

[12] DNR uses two decimal places throughout this report for consistency. However, in this sector four decimal places are needed show the difference in CH_4 emissions from year to year.

[13] Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Table 25: Total CH_4 and N_2O Emissions from Mobile Sources ($MMtCO_2e$)[14, 15]

Fuel /Vehicle Type	2011	2012	2013	2014	2015
Gasoline Highway	0.25	0.23	0.20	0.20	0.18
Diesel Highway	0.01	0.005	0.004	0.005	0.004
Non-Highway	0.04	0.05	0.04	0.05	0.04
Alternative Fuels	0.004	0.004	0.005	0.005	0.005
Total	**0.31**	**0.28**	**0.25**	**0.25**	**0.23**

Figure 9. 2015 GHG Emissions per Fuel/Vehicle Type

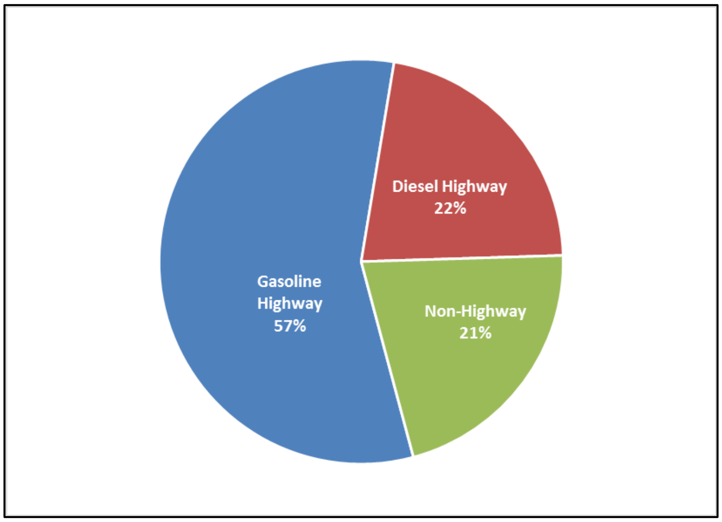
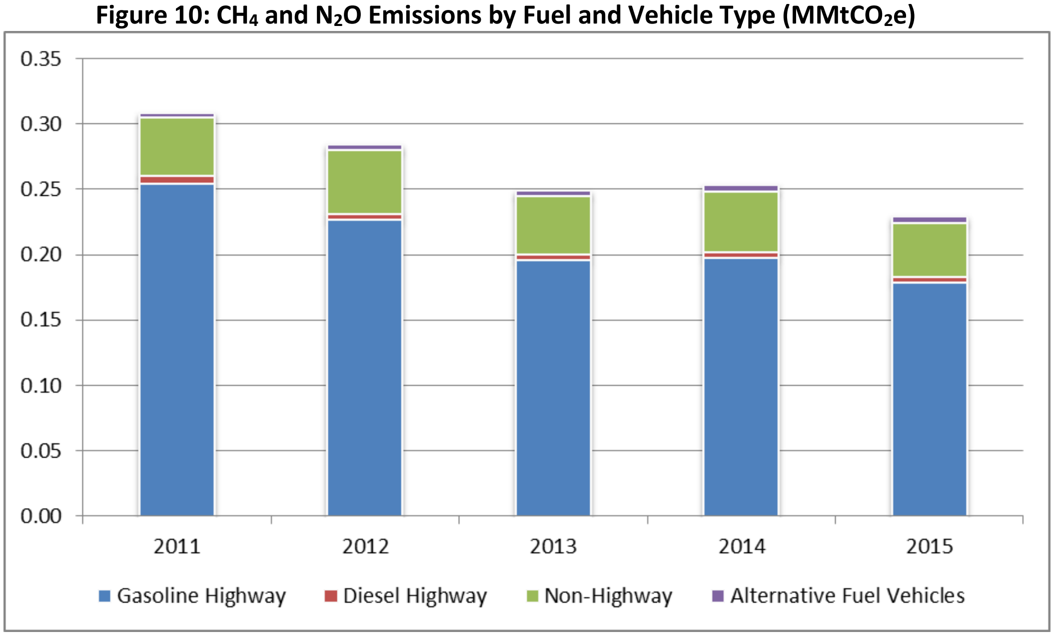


Figure 10: CH_4 and N_2O Emissions by Fuel and Vehicle Type ($MMtCO_2e$)



[14] Totals may not equal the sum of subtotals shown in this table due to independent rounding.
[15] DNR uses two decimal places throughout this report for consistency. However, in this sector additional decimal places are needed show the difference in CH_4 emissions from year to year.

Uncertainty

Uncertainty occurs because national vehicle/fuel type, age distributions, and emission factors, which may not be reflective of Iowa conditions, were applied to Iowa-specific VMT data. There is also some uncertainty in the method EPA used to develop the national vehicle/fuel type distributions and to develop emission factors (EPA 2016). The VMT used for alternative fuel vehicles has a higher level of uncertainty because the DNR was unable locate Iowa-specific VMT data. Uncertainty may be introduced if the fuel consumption data or emission factors used do not reflect Iowa scenarios, such as using default national emission factors. In addition, it is assumed that all fuel purchased is consumed in the same year (ICF 2016b).

Aviation CH_4 and N_2O emissions have a higher level of uncertainty because the jet fuel and aviation gasoline fuel data used is the total quantity of those fuels purchased in Iowa and includes fuel that may be consumed during interstate or international flights (Strait et al. 2008).

Chapter 7 – Waste: Solid Waste

This chapter includes methane (CH_4) emissions from municipal solid waste landfills and carbon dioxide (CO_2) and nitrous oxide (N_2O) emitted from the combustion of municipal solid waste to produce electricity. CH_4 emissions from landfills are a function of several factors, including the total quantity of waste in municipal solid waste landfills; the characteristics of the landfills such as composition of the waste, size, climate; the quantity of CH_4 that is recovered and either flared or combusted in landfill-gas-to-energy (LFGTE) projects; and the quantity of CH_4 oxidized in landfills instead of being released into the atmosphere. Fluctuations in CH_4 emissions can be caused by changes in waste composition, the quantity of landfill gas collected and combusted, the frequency of composting, and the rate of recovery of degradable materials such as paper and paperboard (EPA 2011).

Method

Municipal Solid Waste (MSW) Landfills

The DNR used emissions reported by MSW landfills to the EPA GHGRP (EPA 2016), which are calculated based on the characteristics of each individual report. EPA requires MSW landfills that emit 25,000 metric tons CO_2e or more to report their emissions. This included twenty-two Iowa landfills in 2015. An additional twenty-five Iowa MSW landfills were not required to report to the GHGRP. To calculate emissions for those that did not report to the GHGRP, the DNR calculated the potential methane emissions using EPA's Landfill Gas Emissions Model (LandGEM) version 3.02. LandGEM is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in MSW landfills (EPA 2005).

Combustion of Municipal Solid Waste

The amount of CH_4 emitted from power plants burning MSW to produce electricity was calculated using data reported annually by individual facilities to the DNR's Air Quality Bureau on their annual air emissions inventories (DNR 2016). One facility reported burning a total of 25,429 tons of municipal solid waste in 2015.

The DNR used state-specific proportions of discards that are plastics, synthetic rubber, and synthetic fibers instead of SIT default values to calculate CO_2 emissions from MSW combustion. These state-specific proportion values are from the 2011 Iowa Statewide Waste Characterization Study (MSW 2011). The state-specific proportions of discards used are shown in Table 26 below.

Table 26: Proportions of Discards used in the Solid Waste Module

Material	SIT Default Value[16]	2011 Iowa Study
Plastics	17.0 – 18.0%	16.7%
Synthetic Rubber[17]	2.3 – 2.6%	1.0%
Synthetic Fibers[18]	5.6 – 6.3%	4.1%

[16] Default values for 2005 – 2008.

[17] The 2011 Iowa waste characterization studies identify this material as "rubber".

[18] The 2011 Iowa waste characterization studies identify this material as "textiles and leather".

Plastics and synthetic rubber materials may be further divided in the SIT into subcategories of plastics and rubber (e.g. polyethylene terephthalate (PET), polyvinyl chloride (PVC), polystyrene (PS), etc.), but the subcategories in the SIT do not match the subcategories in the waste characterization study. Therefore, the DNR did subcategorize the proportion of municipal solid waste discards.

Adjustments

Solid waste landfill emissions from 2010 – 2014 were corrected to include emissions from additional landfills that were not used last year's calculations.

Table 27: Recalculated MSW Landfills ($MMtCO_2e$)

Year	Value Published Dec. 2014	Updated Value
2010	1.26	1.28
2011	1.24	1.33
2012	1.42	1.46
2013	1.26	1.30
2014	1.25	1.29

Results

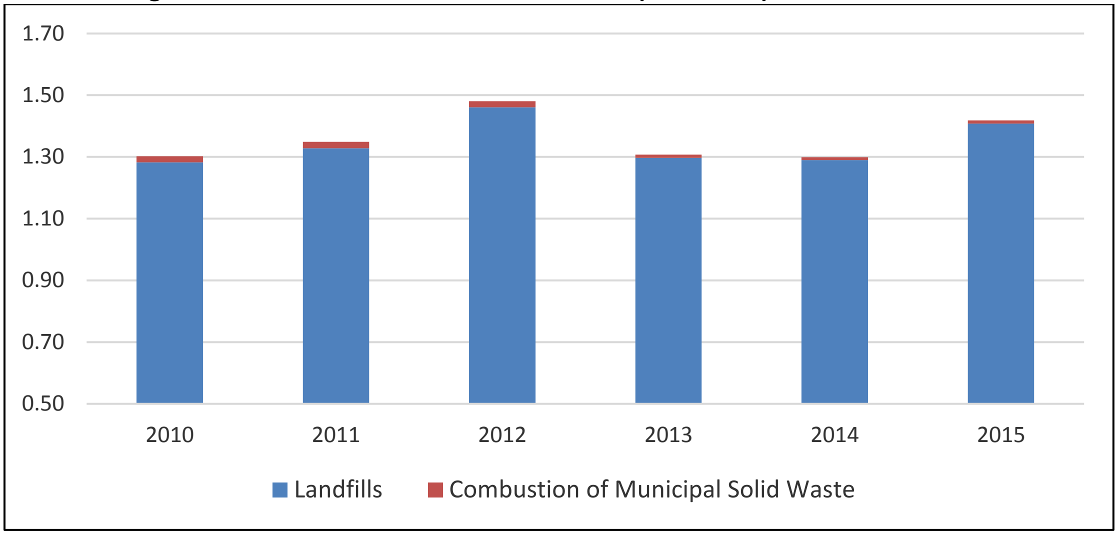
Total GHG emissions from the solid waste category were 1.42 $MMtCO_2e$ in 2015, an increase of 9.20% from 2014 as shown in Table 28 and Figure 11 on the next page. Emissions from 2010 – 2015 cannot be directly compared to prior years because of the change in the calculation method starting with 2010. Emissions from municipal solid waste increased in 2015 because the cumulative amount of waste in landfills increased and less landfill gas was flared off and combusted than in the previous .

Table 28: GHG Emissions from Municipal Solid Waste ($MMtCO_2e$) [19]

Pollutant	2010	2011	2012	2013	2014	2015
MSW Landfills	1.28	1.33	1.46	1.30	1.29	1.41
MSW Combustion	0.02	0.02	0.02	0.01	0.01	0.01
Total	**1.30**	**1.35**	**1.48**	**1.31**	**1.30**	**1.42**

[19] Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 11: GHG Emissions from Solid Waste (MMtCO$_2$e)



Uncertainty

Excerpted from SIT Solid Waste Module (ICF 2016):

MSW Landfills

The methodology does not account for characteristics of individual landfills that impact CH_4 emissions such as temperature, rainfall, landfill design, and the time period that the landfill collects waste. The methodology also assumes that the waste composition of each landfill is the same. The SIT also assumes that 10% of CH_4 is oxidized during diffusion through the soil cover over landfills. This assumption is based on limited information. The methodology also does not account for the presence of landfill gas collection systems that may affect activity in the anaerobic zones of landfills since active pumping may draw more air into the fill (ICF 2016).

MSW Combustion

There are several sources of uncertainty in this sector, including combustion and oxidation rates, average carbon contents, and biogenic content.

- The combustion rate is not exact and varies by the quantity and composition of the waste.
- The oxidation rate varies depending on the type of waste combusted, moisture content, etc.
- The SIT uses average carbon contents instead of specific carbon contents for other plastics, synthetic rubber, and synthetic fibers.
- Non-biogenic CO_2 emissions vary depending on the amount of non-biogenic carbon in the waste and the percentage of non-biogenic carbon that is oxidized.
- The SIT assumes that all carbon in textiles is non-biomass carbon and the category of rubber and leather is almost all rubber. This may result in CO_2 emissions being slightly over-estimated (ICF 2016).

Chapter 8 – Waste: Wastewater Treatment

This chapter includes GHG emissions from the treatment of municipal and industrial wastewater. The pollutants from this sector are methane (CH_4) and nitrous oxide (N_2O). CH_4 is emitted from the treatment of wastewater, both industrial and municipal. CH_4 is produced when organic material is treated in anaerobic environment (in the absence of oxygen) and when untreated wastewater degrades anaerobically. N_2O is produced through nitrification followed by incomplete denitrification of both municipal and industrial wastewater containing both organic and inorganic nitrogen species. Production and subsequent emissions of N_2O is a complex function of biological, chemical, and physical factors, and emission rates depend on the specific conditions of the wastewater and the wastewater collection and treatment system. Human sewage makes up a signification portion of the raw material leading to N_2O emissions (ICF 2016b).

<u>Method</u>

Municipal Wastewater

GHG emissions from municipal wastewater are calculated in the SIT by multiplying a series of emission factors by the annual Iowa population, which was updated for 2015 (U.S. Census 2016). For example, to calculate CH_4 emissions, the state population was multiplied by the quantity of biochemical oxygen demands (BOD) per person emission factor, by the fraction that is treated anaerobically, and by the quantity of CH_4 produced per metric ton. It does not account for any digester methane that is collected and combusted instead of fossil fuels in equipment such as boilers, generators, or flares.

SIT default emission factors and assumptions were used to calculate both CH_4 and N_2O emissions, except that N_2O was calculated using the most recent protein (kg/person-year) value (45.2) from Table 7-15 in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014* (EPA 2016b). Because the 2015 protein value was not available at the time of publication, the 2014 value was used as a surrogate for 2015.

The Iowa fraction of population without septic systems, 76%, from EPA's *Onsite Wastewater Treatment Systems Manual* (EPA 2002), was also used to estimate N_2O emissions. This value taken from the *1990 Census of Housing* and is lower than the SIT default value of 79%. The *2000 Census of Housing* and *2010 Census of Housing* do not include the Iowa fraction of population without septic systems.

Industrial Wastewater

In 2015, the DNR refined its method for calculating emissions from industrial wastewater. The DNR previously calculated emissions usingthe SIT and statewide red meat production numbers from the USDA. This method had a great deal of uncertainty as it only calculated emissions from wastewater at meat processing facilities and because it assumed a set amount of emissions from each metric ton of meat processed.

For this inventory, the DNR used GHG emissions reported by industrial wastewater facilities to EPA's mandatory greenhouse gas reporting program (GHGRP). This includes emissions from five food processng facilities, and seventeen ethanol production faclities. Although only food processors and ethanol production facilities that emit 25,000 metric tons CO_2e or more are required to report to EPA, the emissions reported have a higher level of accuracy than the SIT method because they are based on the unique characteristics and wastewater organic content of each facility. Last year twenty-one ethanol production facilities emitted more than 25,000 metric tons CO_2e or more (EPA 2016a).

Adjustments

Municipal Wastewater N_2O emissions for 2010 - 2014 were recalculated as shown in Table 29 using the updated available protein from Table 7-15 in the most recent national GHG inventory (EPA 2016b).

Table 29: Recalculated Municipal Wastewater N_2O Emissions[20]

	2014 Value Published Dec. 2015		2014 Updated Value	
Year	Protein kg/person/year	$MMtCO_2e$	Protein kg/person/year	$MMtCO_2e$
2010	41.0	0.0880	43.8	0.0939
2011	41.1	0.0887	45.0	0.0969
2012	41.2	0.0893	45.1	0.0974
2013	41.3	0.0899	45.1	0.0980
2014	41.3	0.0904	45.2	0.0987

Results

Wastewater emissions account for 0.31% of total statewide GHG emissions. Total emissions from the wastewater treatment sector were 0.40 $MMtCO_2e$ in 2015, a 1.08% increase from 2014 and an 11.18% decrease from 2005 as shown in Table 30. This is due to increases in the amount of wastewater produced by industrial meat processing facilities and the amount of municipal wastewater produced humans as the state's population increases.

CH_4 and N_2O from municipal wastewater treatment accounted for 78.02% (0.30 $MMtCO_2e$) of total wastewater treatment GHG emissions as shown in Figure 12 below.

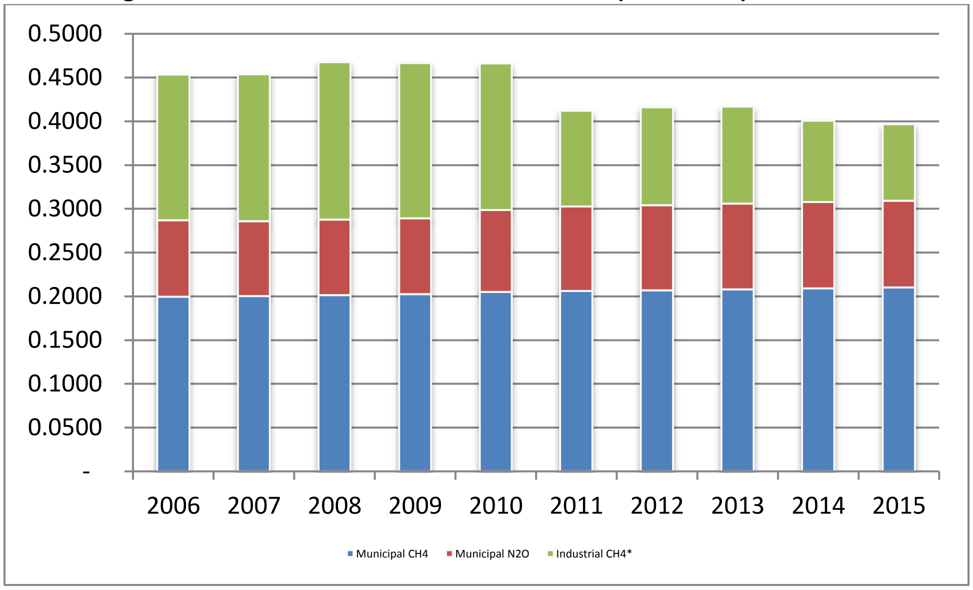
Table 30: GHG Emissions from Wastewater ($MMtCO_2e$)[21]

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Municipal CH_4	0.20	0.20	0.20	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.21
Municipal N_2O	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10
Industrial CH_4	0.17	0.17	0.17	0.18	0.18	0.17	0.11	0.11	0.11	0.09	0.09
Total	**0.45**	**0.45**	**0.45**	**0.47**	**0.47**	**0.47**	**0.41**	**0.42**	**0.42**	**0.40**	**0.40**

[20] DNR uses two decimal places throughout this report for consistency. However, in this sector four decimal places are needed show the difference in CH_4 emissions from year to year.

[21] Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Figure 12: GHG Emissions from Wastewater (MMtCO$_2$e)



*Does not include emissions from production of fruits and vegetables, pulp and paper.

Uncertainty

Excerpted from SIT Wastewater Module (ICF 2016a):

Municipal Wastewater

Uncertainty is associated with both the emission factors and activity data used to calculate GHG emissions. The quantity of CH_4 emissions from wastewater treatment is based on several factors with varying degrees of uncertainty. For human sewage, there is some degree of uncertainty associated with the emission factor used to estimate the occurrence of anaerobic conditions in treatment systems based on septic tank usage data. While the Iowa-specific percentage of the population without septic systems was used to calculate emissions, the value is from 1990. There can also be variation in the per-capita BOD production association with food consumption, food waste, and disposal characteristics for organic matter. Additionally, there is variation in these factors that can be attributed to differences in wastewater treatment facilities (ICF 2016a).

N_2O emissions are dependent on nitrogen (N) inputs into the wastewater and the characteristics of wastewater treatment methods. Estimates of U.S. population, per capita protein consumption data, and the fraction of nitrogen in protein are believed to be fairly accurate. However, the fraction that is used to represent the ratio of non-consumption nitrogen also contributes to the overall uncertainty of these calculations, as does the emission factor for effluent, which is the default emission factor from IPCC (1997). Different disposal methods of sewage sludge, such as incineration, landfilling, or land-application as fertilizer also add complexity to the GHG calculation method (ICF 2016a).

Industrial Wastewater

GHG emissions from industrial wastewater may be underestimated because only industrial wastewater facilities that emit 25,000 $mtCO_2e$ or more are required to report to the federal greenhouse gas reporting program. Future improvements to the inventory could include identifying all of the industrial wastewater facilities that are not required to report to the federal program and developing a method to calculate their emissions.

Chapter 9 - Land Use, Land Use Change, and Forestry (LULUCF)

This chapter addresses carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions from liming of agricultural soils and fertilization of settlement soils, as well as carbon sequestered by forests, urban trees, and yard waste and food scraps that are sent to the landfill.

Method

Forest Carbon Flux

CO_2 is taken in by plants and trees and converted to carbon in biomass during photosynthesis. "Growing forests store carbon naturally in both the wood and soil. Trees are about fifty percent carbon, and wood products from harvested trees continue to store carbon throughout their lives as well" (Flickinger 2010). CO_2 is emitted by live tree respiration, decay of dead material, fires, and biomass that is harvested and used for energy (Strait et al. 2008). The balance between the emission of carbon and the uptake of carbon is known as carbon flux (ICF 2016).

The annual forest carbon flux was calculated using carbon storage statistics from the USDA Forest Service's *Forest Inventory Data Online (FIDO) (*USFS 2016). FIDO data used to calculate sequestration/emission included the following forest categories:

- Carbon in live trees and saplings above ground on forest land
- Carbon in understory above ground on forest land
- Carbon in live trees and saplings below ground on forest land
- Carbon in understory below ground on forest land
- Carbon in standing dead trees on forest land
- Carbon in down dead trees on forest land
- Carbon in litter (shed vegetation decomposing above the soil surface) on forest land
- Soil organic carbon on forest land

Because 2016 carbon storage statistics were not available to calculate the 2015 carbon storage flux (2016 storage minus 2015 storage), the 2015 flux was assumed to be the same as the previous year.

Liming of Agricultural Soils

CO_2 is emitted when acidic agricultural soils are neutralized by adding limestone or dolomite. The Iowa Limestone Producers Association (ILPA) provided the DNR with the total annual amount of limestone produced for agricultural use as reported by their members (Hall 2016). However, producers do not report the percentage of limestone that is dolomitic. The Iowa Department of Transportation (DOT) tracks general information for active aggregate sources used for construction, including whether the material is limestone or dolomite. They do not track that information for limestone produced for agricultural purposes. The DOT indicated that some areas of the state have 100% dolomite, some have 100% limestone, and some areas are mixed (Reyes 2011). Therefore, the DNR assumed that 50% of the material produced in Iowa for agricultural use is dolomite and 50% is limestone.

Urea Fertilization

Urea emissions were calculated using the amount of urea applied annually (IDALS 2016). Because the amount of urea fertilizer applied in the in last six months of 2015 was not available; so the amount applied from July 2014 – December 2014 (71,462 tons) was used as a surrogate for the amount applied from July 2015 – December 2015.

Urban Tree Flux

Carbon sequestration estimations from this sector were refined by using a new DNR data set that is a mix of land cover/remote sensing data with about a one-meter resolution. The data set includes the amount of forested acres and total acres of land for 946 incorporated areas in Iowa (Hannigan, 2014).

Settlement Soils

Approximately 10% of the fertilizers applied to soils in the United States are applied to soils in settled areas such as landscaping, lawns, and golf courses (ICF 2016). N_2O emissions from settlement soils were calculated using 10% of the total annual growing year synthetic fertilizer value from the SIT Agriculture module. For more information on how the 2016 values were derived, please see *Chapter 2-Agriculture* of this report.

Non-CO_2 Emissions from Forest Fires

CH_4 and N_2O emissions from forest fires in Iowa were not estimated because the majority of wildfires and prescribed burns in Iowa that are reported to DNR occur on grasslands (Kantak 2014). In addition, the SIT calculation method uses combustion efficiencies and emission factors that are provided for primary tropical forests, secondary tropical forests, tertiary tropical forests, boreal forest, eucalypt forest, other temperate forests, shrub lands, and savanna woodlands, which are not reflective of Iowa vegetation.

Yard Trimmings and Food Scraps Stored in Landfills

GHG estimations from this sector were refined by applying the estimated percentages of yard waste and food waste in municipal solid waste from the *2011 Iowa Statewide Waste Characterization Study* (MSW 2011) to the total amount of municipal solid waste sent to landfills in 2015 (DNR 2016). While the DNR was able to use more accurate Iowa values for the annual amounts of yard waste and food scraps stored in landfills, the DNR used the SIT default values for content of yard trimmings (e.g. % grass, % leaves, % branches), carbon content, proportion of carbon stored permanently, and half-life of degradable carbon because Iowa-specific data was not available.

Adjustments

Forest Carbon Flux

The 2014 forest carbon flux value was recalculated using data from the USDA Forest Service's *Forest Inventory Data Online* (USFS 2016). In the previous inventory, the 2013 carbon flux value was used as a surrogate for 2014. The previous reported value was -1.02 $MMtCO_2e$. The revised value is +3.04 $MMtCO_2e$. This changed the total emissions from the LULUCF sector in 2014 from 0.79 $MMtCO_2e$ *sequestered* to 3.28 $MMtCO_2e$ *emitted*.

Urea Fertilization

2013 and 2014 emissions were recalculated using the most recent activity data available (IDALS 2016) as shown in Table 31. This resulted in a decrease of 0.02 $MMtCO_2e$ tons in 2013 and an increase of 0.02 $MMtCO_2e$ in 2014.

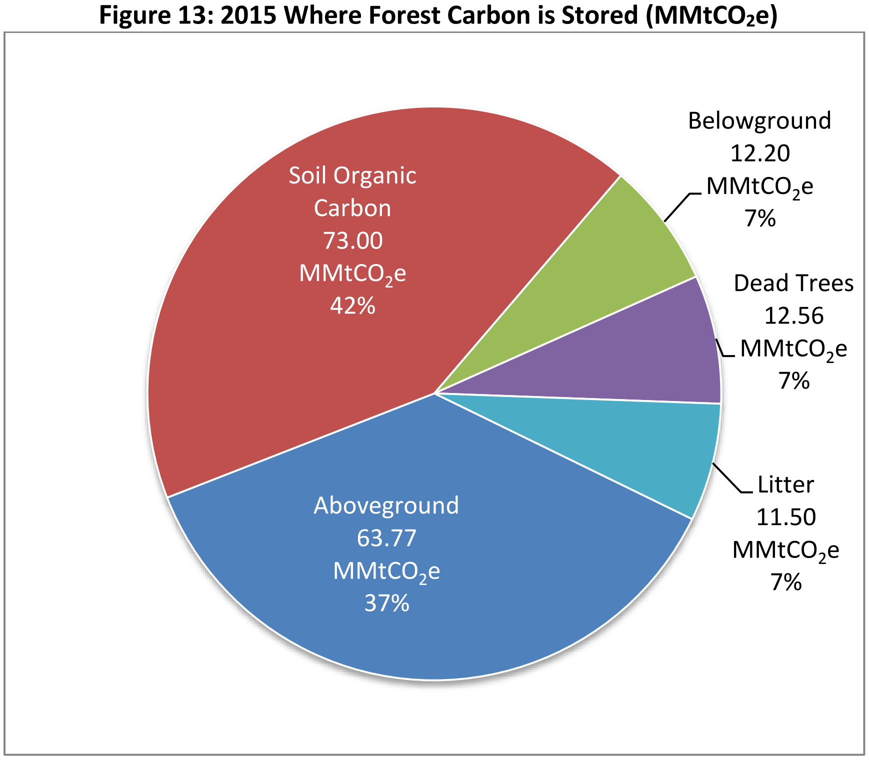
Table 31: Updated Urea Application (metric tons urea applied)

Year	Value Used in Dec. 2015 Report	Updated Value
2013	177,273	155,048
2014	177,273	209,519

Results

The majority of forest carbon is stored in above ground living trees (37%) and in the forest soil (42%) as shown in Figure 13 below.

Figure 13: 2015 Where Forest Carbon is Stored ($MMtCO_2e$)

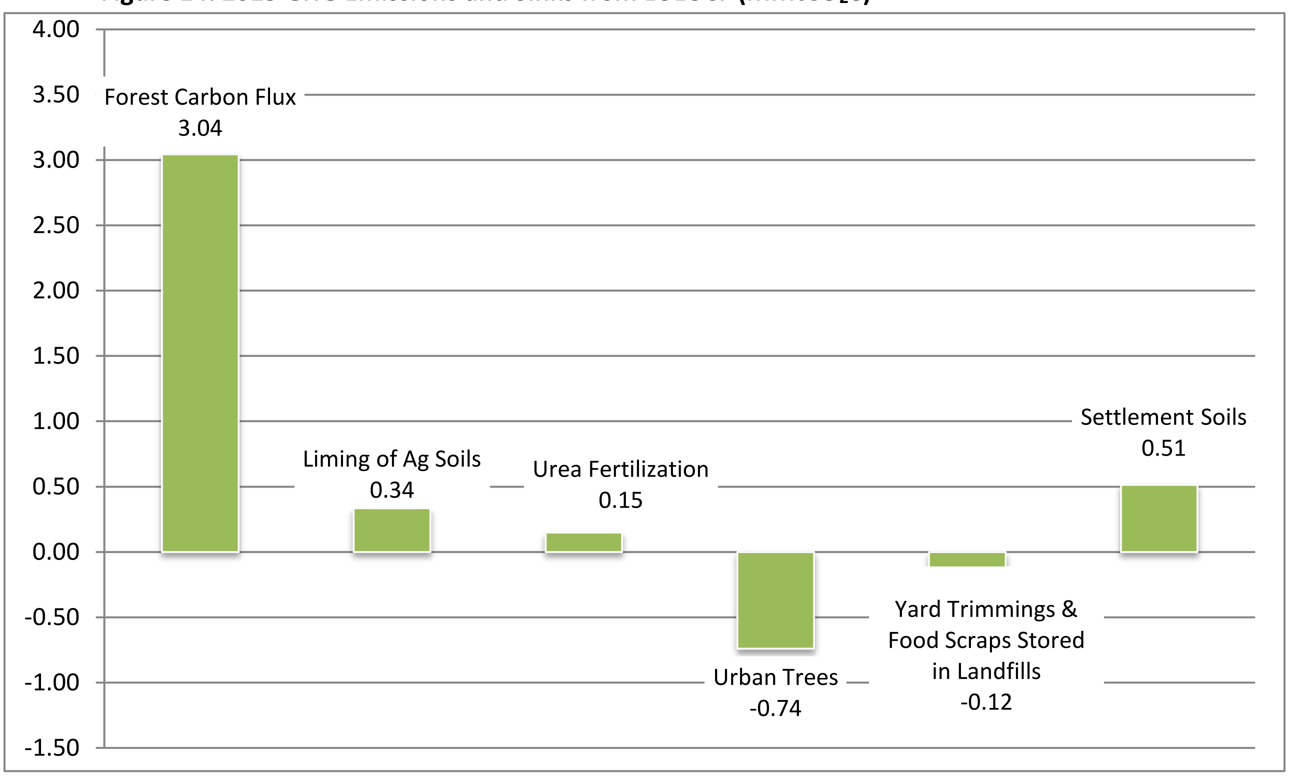


Overall, sources in the LULUCF sector released more carbon than they stored in 2015, emitting a total of 3.18 $MMtCO_2e$ as shown in Table 32 and Figure 14 below. This is a decrease of 3.30% from 2014 and a decrease of 115.49% from 2005. Emissions of CO_2 are shown above the x-axis in Figure 14 and carbon sinks are shown below the x-axis.

Table 32: GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)[22]

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Forest Carbon Flux	-21.24	-6.53	+2.70	-4.48	-5.47	-2.68	-0.14	-0.47	-1.02	3.04	3.04
Liming of Ag Soils	+0.42	+0.45	+0.37	+0.28	+0.27	+0.47	+0.51	+0.65	+0.47	+0.41	+0.34
Urea Fertilization	+0.15	+0.15	+0.15	+0.15	+0.12	+0.11	+0.12	+0.13	+0.11	+0.15	+0.15
Urban Trees	-0.25	-0.25	-0.25	-0.26	-0.26	-0.28	-0.28	-0.28	-0.74	-0.74	-0.74
Yard Trimmings & Food Scraps Stored in Landfills	-0.09	-0.09	-0.08	-0.09	-0.10	-0.10	-0.13	-0.12	-0.11	-0.12	-0.12
N_2O from Settlement Soils	+0.46	+0.48	+0.53	+0.49	+0.44	+0.48	+0.56	+0.57	+0.55	+0.55	+0.51
Total	**-20.54**	**-5.79**	**+3.41**	**-3.91**	**-5.00**	**-2.00**	**+0.66**	**0.48**	**-0.74**	**3.29**	**3.18**

Figure 14: 2015 GHG Emissions and Sinks from LULUCF ($MMtCO_2e$)



[22] Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

Uncertainty

Uncertainty in the LULUCF sector is due to the lack of current Iowa-specific data and emission factors used to calculate emissions and/or sinks from urban trees and settlement soils. Emissions from categories such as urea fertilization, liming of agricultural soils, and yard waste and food scraps stored in landfills are more certain because Iowa-specific activity data was used. However, uncertainty was also introduced by using surrogate urea data for the last six months of 2015, using growing year synthetic fertilizer data for settlement soils instead of calendar year data, assuming the ratio of limestone to dolomite in Iowa is 50%, and using SIT default values for content of yard trimmings (e.g. % grass, % leaves, % branches), carbon content, proportion of carbon stored permanently and half-life of degradable carbon. In addition, due to the high uncertainty in soil carbon flux from tillage practices, it was not included in the DNR's calculations. Refer to *Chapter 2 – Agriculture* for more information.

Chapter 10 – Electricity Consumption

This chapter includes indirect emissions from electricity consumed at the point of use (e.g. residential electric hot water heaters, televisions, appliances, etc.) and does not include direct emissions generated at the electric power generating station (*see Chapter 3 – Fossil Fuel Combustion*).

Electricity consumed by Iowans may not be generated in Iowa. Because of this, emissions from electricity consumption do not match emissions from electricity generation (ICF 2016b). Therefore, GHG emissions from electricity consumption are included in this inventory as an informational item only and are not included in the total statewide GHG emissions to avoid any possible double-counting. However, trends in electricity consumption are valuable because they are indicators of consumer behavior and trends in energy efficiency.

<u>Method</u>

GHG emissions were calculated using the Electricity Consumption SIT module (ICF 2016a).

Residential, Commercial, and Industrial

2015 emissions were projected by applying the forecasted percent change in energy consumption for each sector for the West North Central Region in the EIA's *Annual Energy Outlook (AEO) 2016 with Projections to 2040* (EIA 2016a) to Iowa's 2014 electricity consumption data from EIA (EIA 2016b).

Transportation

This is the first year that the DNR has calculated indirect emissions from electricity consumption in the transportation sector. According to the June 2016 report *Advancing Iowa's Electric Vehicle Market* (IEDA 2016), 1,017 electric vehicles were registered in Iowa as of June 2016. This is 0.03% of the total number of vehicles, 4.34 million, registered in the state in 2015 (IDOT 2016). Emissions were calculated assuming that each electric vehicle consumes 4,250 kWh of electricity per year (IEDA 2016) and rounded to less than 0.005 $MMtCO_2e$ as shown in Table 34. This does not include emissions from electric propulsion, other electric batteries, or non-highway electric vehicles such as golf carts.

<u>Adjustments</u>

2014 emissions have been updated since the DNR's 2014 GHG Inventory Report was published in December 2015. The DNR previously forecasted 2014 emissions due to a lack of Iowa-specific bulk energy consumption data. However, the 2014 energy data was released by EIA in June 2016 (EIA 2016b), so the DNR used the data to recalculate 2014 emissions as shown in Table 33 and Table 35. In addition, EPA has updated both the electricity emission factor and transmission loss factor based on updated data in its 2012 Emissions & Generation Resource Integrated Database (eGRID 2015) as shown in Table 34.

Table 33: Updated 2014 Activity Data

Category	2014 Value Used in Dec. 2015	2014 Updated Value
Electricity Consumption (kWh)		
Residential	14,655,327,686	14,427,000,000
Commercial	12,459,722,622	12,339,000,000
Industrial	19,643,055,786	20,436,000,000
Total	**46,758,106,094**	**47,202,000,000**
Electricity Emission Factor (lbs. CO_2e/kWh)	1.6334632	1.4103402
Transmission Loss Factor (%)	5.8224%	9.1703%

Table 34: Recalculated Electricity Emissions ($MMtCO_2e$)

Category	2014 Value Published Dec. 2015	2014 Updated Value
Residential	11.53	10.16
Commercial	9.80	8.69
Industrial	15.45	14.39
Total	**36.79**	**33.24**

Results

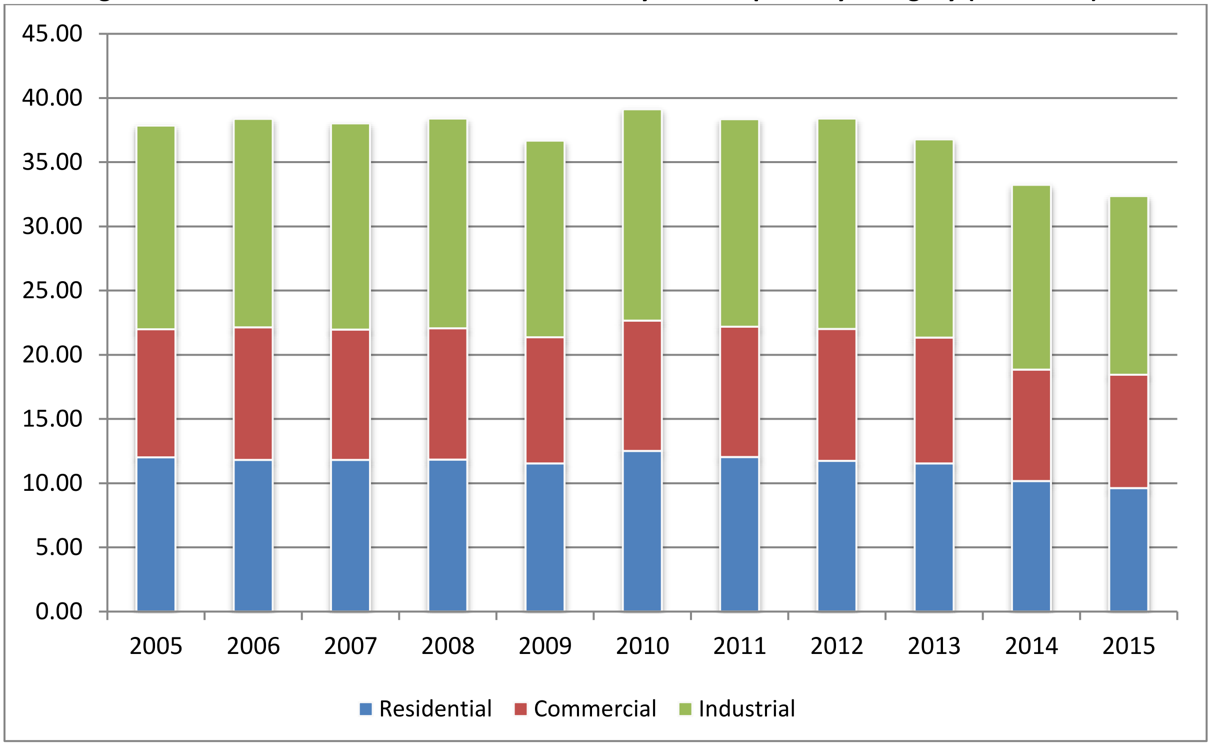
Indirect GHG emissions from electricity consumption were 32.37 $MMtCO_2e$ in 2015, decreasing 2.62% since 2014, mostly due to a projected 5.30% decrease in residential electricity consumption. Industrial users consumed 43.00% of electricity in the state, while residential users consumed 29.72% and commercial users consumed 27.28% as shown in Table 35 and Figure 15 below.

Table 35: GHG Emissions from Electricity Consumption ($MMtCO_2e$)[23]

Sector/Fuel Type	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Residential	12.02	11.82	11.81	11.83	11.53	12.52	12.04	11.75	11.53	10.16	9.62
Commercial	9.98	10.33	10.15	10.23	9.84	10.13	10.16	10.26	9.80	8.69	8.83
Industrial	15.86	16.23	16.07	16.33	15.30	16.48	16.17	16.39	15.45	14.39	13.92
Transportation	*not calculated*										0.00
Total	**37.86**	**38.38**	**38.04**	**38.39**	**36.67**	**39.13**	**38.36**	**38.41**	**36.79**	**33.24**	**32.37**

[23] Totals may not equal the sum of subtotals shown in this table due to independent rounding.

Figure 15: Indirect GHG Emissions from Electricity Consumption by Category ($MMtCO_2e$)



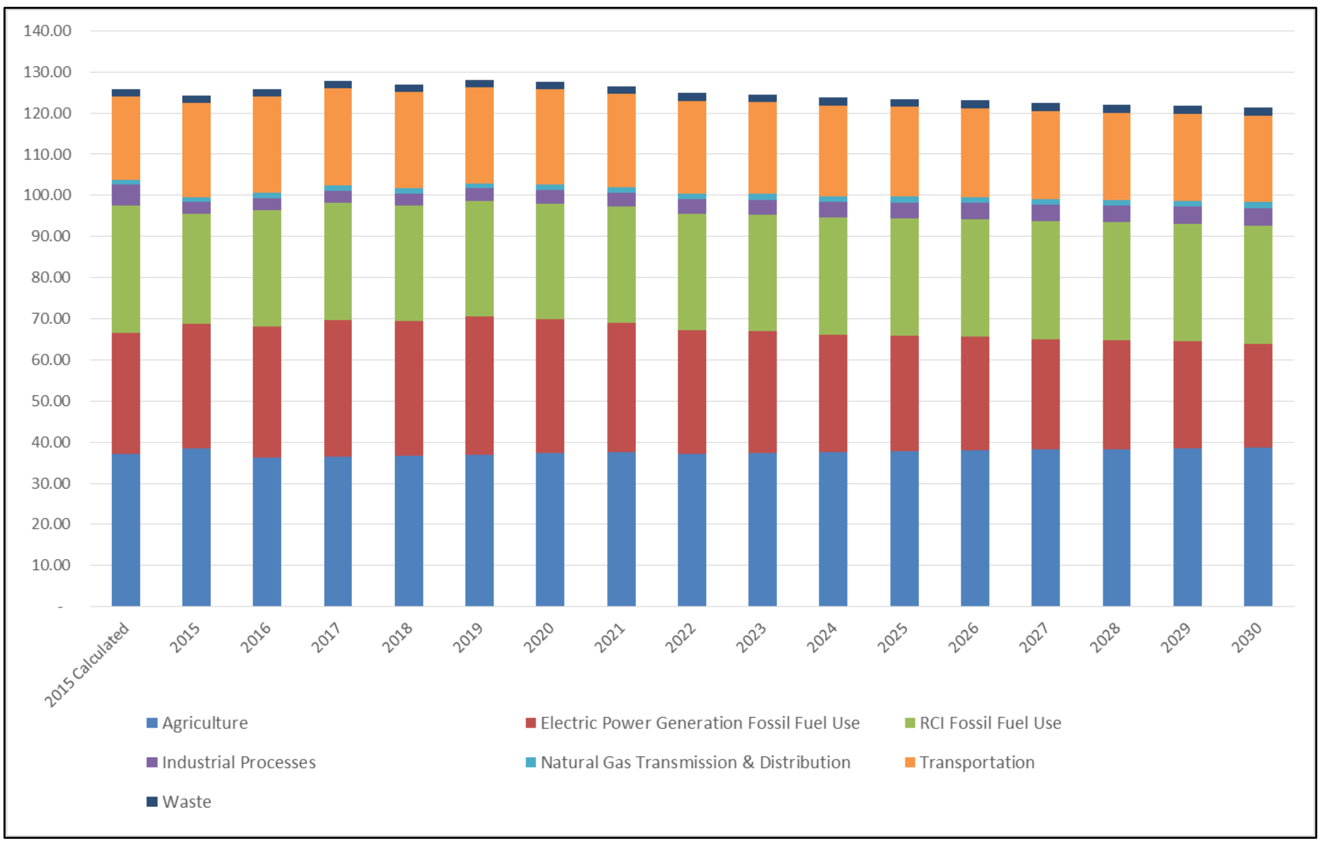
Forecasting

Iowa Code 455B.104 requires that the DNR forecast trends in GHG emissions. The DNR projected emissions from 2015 to 2030 using the SIT Projection Tool (ICF 2014). As with many forecasts, there are numerous factors that affect the significant level of uncertainty with future emissions. These factors may include among other things - the economy, weather, current and future environmental regulations, energy efficiency and conservation practices, driving practices, use of renewable fuels, etc.

The SIT projects that Iowa's population decreases every year from 2012 – 2030. This is contrary to the most recent population projections available from the State Data Center (Woods & Poole, 2009). Consequently, the DNR replaced the SIT default populations with the actual Iowa population for 2012 - 2015 (U.S. Census 2016) and the 2020, 2025, and 2030 projections from Woods & Poole Economics. The data points for the intervening years were calculated using a linear interpretation.

The projected emissions for 2015 – 2030 for each category are shown in Figure 16 below. The SIT Projection Tool forecasts emissions from industrial processes, agriculture, and waste based on historical emissions from 1990 – 2012, using a combination of data sources and national projections for activity data.

Figure 16: Projected Gross GHG Emissions 2015 – 2030 (MMtCO$_2$e)



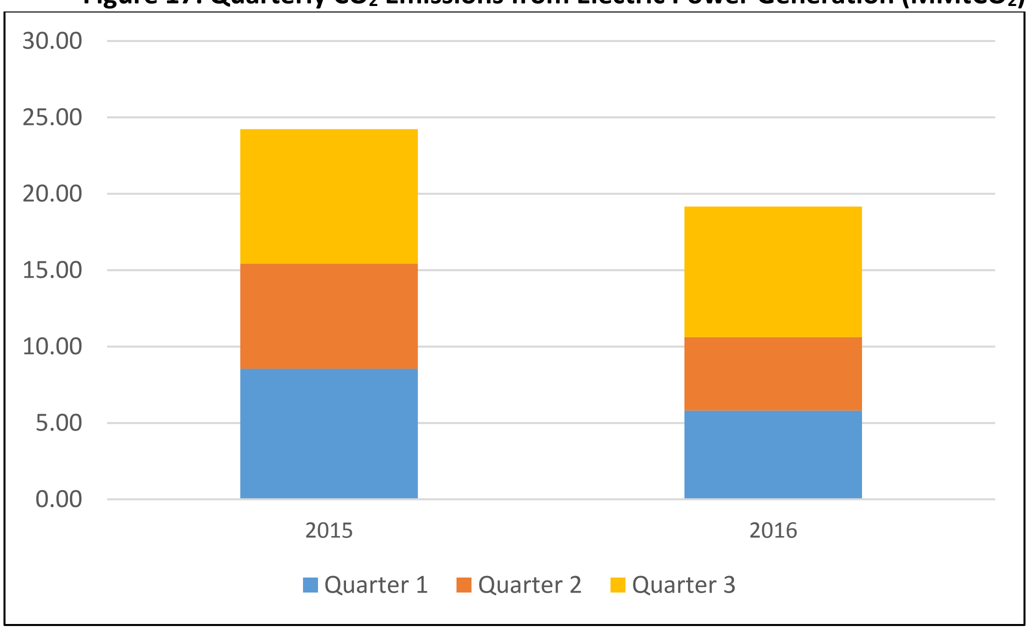
The energy forecast is based on projected energy consumption values from the EIA's *Annual Energy Outlook (2016) with Projections to 2040* (EIA 2016a). The AEO2016 includes several different projection cases, which each address different uncertainties. The DNR used the AEO2016 "Reference Case", which represents federal and state legislation and final implementation of regulations as of the end of February 2016.

Short-term Projections for the Electric Power Sector

In October 2016, the U.S. Energy Information Administration of the Department of Energy announced (EIA 2016b) that CO_2 emissions in the national energy sector during the first six months of 2016 decreased to their lowest levels since 1991. EIA attributes this to mild weather, decreasing coal use and increased electricity generation from zero-emitting sources such as wind, solar, and hydropower.

The most recent emissions data available for Iowa power plants follows similar trends. Data from EPA's Clean Air Markets Division (CAMD 2016) shows that CO_2 emissions from the electric power generation during the first nine months of 2016 are 20.92% lower than CO_2 emissions from the first nine months of 2015 as shown in Figure 17. Decreased emissions are also related to the decreasing price of renewables and the low price of natural gas, which is in turn related to the amount of natural gas from fracking and other market forces. CO_2 emissions from the electric generating facilities may increase if the natural gas price increases.

Figure 17: Quarterly CO_2 Emissions from Electric Power Generation ($MMtCO_2$)



Uncertainty

Although the SIT Projection Tool provides a good first look at projected future emissions, it has several areas of uncertainty:

1. In sectors where the Projection Tool predicts future emissions based on historical emissions, it only uses emissions from 1990 – 2012 and does not consider 2013 - 2015 emissions.

2. Agricultural emissions are highly dependent on the weather and crop and livestock prices, which are not addressed by the Projection Tool.

3. The Projection Tool forecasts emissions from fossil fuel use based on the reference case from the EIA's *Annual Energy Outlook 2016 with Projections to 2040*, which projects emissions at the regional level and not the state level.

4. The Projection Tool does not address publicly announced changes to Iowa's fossil fuel generation mix:

   - Iowa utilities have announced that from 2016 - 2025, approximately 1,000 MW of coal-fired electric generation units will retire or convert to natural gas. During that same time period, approximately 185 MW of older natural gas-fired electric generation units will retire, and approximately 650 MW of newer, more efficient natural gas-fired electric generating units will come online. This will significantly reduce emissions from the electric power sector as natural gas emits approximately 50% less CO_2 per heating unit than coal emits.

   - Approximately 4,000 MW of additional wind generation is planned to come online from 2016 – 2018, and at least an additional 9.5 MW of solar generation is planned to come online from 2016 – 2017.

   - The Projection Tool does not address any future changes in emissions due to the EPA's Clean Power Plan (CPP) rule. The rule requires Iowa to reduce CO_2 emissions from affected energy generating units on the step-down schedule shown in Table 10. Iowa may choose to comply with a rate based-goal or one of two mass based-goals: one including existing sources only or one including both existing and new sources. EPA's implementation of the CPP was stayed by the U.S. Supreme Court on February 9, 2016 and is currently being litigated.

Table 36: EPA Clean Power Plan Interim (2022-2029) and Final Goals (2030) for Iowa

Time Period	CO_2 Rate (lbs./net MWh)	CO_2 Emissions ($MMtCO_2$)[24]	
2012 Historic	2,195	34.60	
		Mass-Based Goal	
	Rate-Based Goal	Existing Sources	Existing & New Sources
Interim Step 1	1,638	27.59	30.53
Interim Step 2	1,472	25.05	28.03
Interim Step 3	1,355	23.57	26.37
Final Goal 2030+	1,283	22.70	25.28

[24] The emissions goals in the Clean Power Plan are in units of tons of CO_2 per year. The mass goals in Table 10 have been converted to million metric tons CO_2 ($MMtCO_2$) per year so that they are comparable to the results of 2015 Iowa Statewide GHG Inventory.

References

Unless otherwise noted, all emails referenced were sent to Marnie Stein, Air Quality Bureau, Iowa Department of Natural Resources, Windsor Heights, Iowa.

General Method

ICF Consulting (2004). Emissions Inventory Improvement Program (EIIP) Volume VIII: Greenhouse Gases. Prepared for the U.S. Environmental Protection and STAPPA/ALAPCO, Washington DC.

IPCC (2001). Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change [Watson, R.T. and the Core Writing Team (Eds.)]. Cambridge University Press, Cambridge, United Kingdom, and New York, New York. Available online at <https://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml>.

IPCC (2007). Climate Change 2007: Synthesis Report. A Contribution of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K. and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland. Available online at <https://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml>.

Agriculture

Baker, J.M. et al. (2007). Tillage and soil carbon sequestration – what do we really know? *Agriculture, Ecosystems, and Environment* 118:1-5.

Blanco-Canqui, H. and R. Lal (2008). No-tillage and soil-profile carbon sequestration: an on-farm assessment. *Soil Science Society of America Journal* 72:693-701.

Boddey, R.M, C.P Jantalia, B. Alves, B. and S. Urquiaga. (2009). “Comments on ‘No-Tillage and Soil-Profile Carbon Sequestration: An On-Farm Assessment’”. Soil Science Society of America Journal 73(2):688.

DNR (2015). “Comments on EPA’s Preliminary 2014 Agricultural and Grass/Pasture Burning Emissions.” Correspondence from Catharine Fitzsimmons, Air Quality Bureau Chief to Venkatesh Rao and George A. Pouliot, U.S. Environmental Protection Agency, Washington DC. June 13, 2015.

EPA (2015). “Ag Burning Emission Factors”. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www3.epa.gov/ttn/chief/net/2014inventory.html>.

EPA (2016). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014. #430-R-16-002. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html >.

Eve, M., D. Pape, M. Flugge, R. Steele, D. Man, M. Riley-Gilbert, and S. Biggar, Eds. (2014). Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory. Technical

Bulletin Number 1939. Office of the Chief Economist, U.S. Department of Agriculture, Washington, DC. Available online at <http://www.usda.gov/oce/climate_change/estimation.htm>.

Franzluebbers, A.J. (2009). "Comments on 'No-Tillage and Soil-Profile Carbon Sequestration: An On-Farm Assessment'" Soil Science Society of America Journal 73(2):686-7.

ICF Consulting (2004). Emissions Inventory Improvement Program (EIIP) Volume VIII: Greenhouse Gases. Prepared for the U.S. Environmental Protection and STAPPA/ALAPCO, Washington DC.

ICF International (2016a). State Inventory Tool – Agriculture Module (draft version). Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 15, 2006.

ICF International (2016b). User's Guide for Estimating Methane and Nitrous Oxide Emissions from Agriculture Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

IDALS (2016). Fertilizer Tonnage Distribution in Iowa for July 1, 2013 – June 30, 2014 and July 1, 2014 – June 30, 2015. Iowa Department of Agriculture and Land Stewardship, Commercial Feed and Fertilizer Bureau. Des Moines, Iowa. Available online at <http://www.iowaagriculture.gov/feedAndFertilizer/fertilizerDistributionReport.asp>.

Kantak, G. (2015). Email correspondence. Gail Kantak, Wildland Fire Supervisor, Iowa Department of Natural Resources, Des Moines, Iowa. February 6, 2015.

Licht, M. (2015). Email correspondence. Mark Licht, Cropping Systems Specialist, Iowa State University Extension, Ames, Iowa. June 6, 2015.

NRCS (2015). Carbon Management and Evaluation Online Tool (COMET-FARM™). National Resources and Conservation Service, Washington DC, and Colorado State University, Ft. Collins, Colorado. Available online at <http://cometfarm.nrel.colostate.edu/>.

Pouliot, George. (2015). Email correspondence. George Pouliot, United States Environmental Protection Agency, Washington, DC. July 30, 2015.

Stein, Marnie. (2015). Email correspondence to George Pouliot. July 30, 2015.

Strait, R. et al. (2008). Final Iowa Greenhouse Gas Inventory and Reference Case Projections 1990 – 2025. Center for Climate Strategies, Washington DC. Available online at <http://www.iowadnr.gov/Environment/ClimateChange.aspx>.

Sucik, M. (2011a). Email correspondence. Michael Sucik, State Soil Scientist, Natural Resources and Conservation Service, Des Moines, Iowa. May 23, 2011.

Sucik, M. (2011b). Email correspondence. Michael Sucik, State Soil Scientist, Natural Resources and Conservation Service, Des Moines, Iowa. December 19, 2011.

USDA (2010). “No-Till” Farming is a Growing Practice. Economic Information Bulletin Number 70. Economic Research Service, U.S. Department of Agriculture, Washington DC. Available online at <http://www.ers.usda.gov/Publications/EIB70/EIB70.pdf>.

USDA (2014a). 2012 Census of Agriculture. U.S. Department of Agriculture, Washington DC. Available online at <http://www.agcensus.usda.gov/Publications/2012/>.

USDA (2014b). 2014 Iowa Agricultural Statistics Bulletin. National Agricultural Statistics Service, U.S. Department of Agriculture, Washington DC. Available online at <http://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/Annual_Statistical_Bulletin/>.

USDA (2015). 2015 Iowa Agricultural Statistics Bulletin. National Agricultural Statistics Service, U.S. Department of Agriculture, Washington DC. Available online at <http://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/Annual_Statistical_Bulletin/>.

USDA (2016a). Conservation Reserve Program – CRP Enrollment and Rental Payments by State, 1986 - 2015. Farm Service Agency, U.S. Department of Agriculture, Washington, DC. Available online at <http://www.fsa.usda.gov/programs-and-services/conservation-programs/reports-and-statistics/conservation-reserve-program-statistics/index>. Accessed on September 19, 2016.

USDA (2016b). Quick Stats 2.0: Agricultural Statistics Database. National Agricultural Statistics Service, U.S. Department of Agriculture, Washington DC. Available online at <http://www.nass.usda.gov/Quick_Stats/>. Accessed August 25, 2016.

West, T., and J. Six (2007). “Considering the Influence of Sequestration Duration and Carbon Saturation on Estimates of Soil Carbon Capacity”. *Climatic Change,* 80(1):25-41.

Wollin, T. and W. M. Stigliani (2005). Year 2000 Iowa Greenhouse Gas Emissions Inventory. University of Northern Iowa, Cedar Falls, Iowa.

Fossil Fuel Consumption

CAMD (2016). Clean Air Markets – Data and Maps. Clean Air Markets Division, U.S. Environmental Protection Agency, Washington D.C. Available online at <https://ampd.epa.gov/ampd/>. Accessed on September 6, 2016.

EIA (2016a) Annual Energy Outlook 2016 with Projections to 2040. Energy Information Administration, U.S. Department of Energy, Washington D.C. Available online at <http://www.eia.gov/forecasts/aeo/data.cfm#enconsec>.

EIA (2016b) State Energy Data System (SEDS) 1960-2014 Completed Data File – Released June 29, 2016. Energy Information Administration, U.S. Department of Energy, Washington DC. Available online at <http://www.eia.gov/state/seds/seds-data-complete.cfm?src=email>. Accessed on September 2, 2016.

EPA (2016). Envirofacts Greenhouse Gas Customized Search. U.S. Environmental Protection Agency, Washington, DC. Available online at <https://www.epa.gov/enviro/greenhouse-gas-customized-search>. Accessed on October 4, 2016.

ICF International (2016a). State Inventory Tool – CO_2FFC. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 15, 2016.

ICF International (2016b). State Inventory Tool – Stationary Combustion. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 15, 2016.

ICF International (2016c). User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

ICF International (2016d). User's Guide for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

IPCC/UNEP/OECD/IEA (1997). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, United Nations Environment Programme, Organization for Economic Co-Operation and Development, International Energy Agency, Paris, France.

Industrial Processes

DNR (2010). Annual Title V Emission Inventory Data 2005 – 2009. Iowa Department of Natural Resources, Des Moines, Iowa.

EIA (2016). Electric Power Annual 2014. Energy Information Administration, U.S. Department of Energy, Washington DC. Available online at <http://www.eia.gov/electricity/annual/>.

EPA (2010). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008. #430-S-10-001. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www3.epa.gov/climatechange/ghgemissions/usinventoryreport/archive.html>.

EPA (2016a). Envirofacts Greenhouse Gas Customized Search. U.S. Environmental Protection Agency, Washington, DC. Available online at <https://www.epa.gov/enviro/greenhouse-gas-customized-search>. Accessed on October 4, 2016.

EPA (2016b). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014. #430-R-16-002. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html >.

ICF Consulting (2004). Emissions Inventory Improvement Program (EIIP) Volume VIII: Greenhouse Gases. Prepared for the U.S. Environmental Protection and STAPPA/ALAPCO, Washington DC.

ICF International (2016a). State Inventory Tool – IP Module (draft version). Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. June 20, 2016.

ICF International (2016b). User's Guide for Estimating Carbon Dioxide, Nitrous Oxide, HFC, PFC, and SF_6 Emissions from Industrial Processes Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

U.S. Census Bureau (2016). U.S. Census Quick Facts. U.S. Census Bureau, Washington DC. Available online at <http://quickfacts.census.gov/qfd/states/19000.html>. Accessed August 26, 2016.

USGS (2016a). Crushed Stone: Mineral Yearbook 2014 [Advanced Release]. Minerals Information Service, U.S. Geological Survey, Reston, Virginia. Available online at <http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/myb1-2014-stonc.pdf>.

USGS (2016b). Soda Ash: Mineral Commodity Summaries 2016. Minerals Information Service, U.S. Geological Survey, Reston, Virginia. Available online at <http://minerals.usgs.gov/minerals/pubs/commodity/soda_ash/mcs-2015-sodaa.pdf>.

WRI (2008). CO_2 Emissions from the Production of Ammonia v. 2.0. World Resources Institute Greenhouse Gas Protocol Initiative, Washington DC. Available online at <http://www.ghgprotocol.org/calculation-tools/all-tools>.

Natural Gas Transmission and Distribution

Data source: DOT (2016). Distribution, Transmission, and Liquid Annual Data 1990 - 2015. Office of Pipeline Safety, Pipeline and Hazardous Materials Safety Administration, U.S. Department of Transportation. Washington DC. Available online at <http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.ebdc7a8a7e39f2e55cf2031050248a0c/?vgnextoid=a872dfa122a1d110VgnVCM1000009ed07898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print>. Accessed on August 26, 2016.

ICF International (2016a). State Inventory Tool – Natural Gas and Oil Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 15, 2016.

ICF International (2016b). User's Guide for Estimating Carbon Dioxide and Methane Emissions from Natural Gas and Oil Systems Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

Little, J. (2011). Email correspondence. Jeff Little. Energy Information Administration. June 8, 2011.

Stursma, D. (2016). Email correspondence. Don Stursma, Safety and Engineering Manager, Iowa Utilities Board, Des Moines, Iowa. August 26, 2016.

Transportation

EIA (2016a) *Adjusted Sales of Distillate Fuel Oil by End Use*. U.S. Energy Information Administration. Washington DC. Available online at <http://www.eia.gov/dnav/pet/pet_cons_821dsta_dcu_SIA_a.htm>.

EIA (2016b) State Energy Data System (SEDS) 1960-2014 Completed Data File – Released June 29, 2016. Energy Information Administration, U.S. Department of Energy, Washington DC. Available online at <http://www.eia.gov/state/seds/seds-data-complete.cfm?src=email>. Accessed on September 2, 2016.

EPA (2016). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014. #430-R-16-002. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html>.

FHWA (2016). FHWA Highway Statistics 2015 – *Private and Commercial Nonhighway Use of Gasoline – 2012 (Table MF-24).* Federal Highway Administration, U.S. Department of Transportation. Available online at <https://www.fhwa.dot.gov/policyinformation/statistics/2014/pdf/mf24.pdf>.

ICF International (2016a). State Inventory Tool – Mobile Combustion. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

ICF International (2016b). User's Guide for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

IDOT (2016). Historical Vehicle Miles of Travel (VMT). Iowa Department of Transportation. Ames, Iowa. Available online at <http://www.iowadot.gov/maps/msp/vmt/30yearvmt.pdf>. Accessed on September 7, 2016.

Strait, R. et al. (2008). Final Iowa Greenhouse Gas Inventory and Reference Case Projections 1990 – 2025. Center for Climate Strategies, Washington DC. Available online at <http://www.iowadnr.gov/Environment/ClimateChange.aspx>.

Waste: Solid Waste

DNR (2016). Annual Title V Emission Inventory Data 2016. Iowa Department of Natural Resources, Des Moines, Iowa.

EPA (2005). Landfill Emission Model (LandGEM) Version 3.02. U.S. Environmental Protection Agency, Washington DC. Available online at <https://www3.epa.gov/ttn/chief/efpac/esttools.html>.

EPA (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. #430-R-11-005. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www3.epa.gov/climatechange/ghgemissions/usinventoryreport/archive.html>.

EPA (2016). Envirofacts Greenhouse Gas Customized Search. U.S. Environmental Protection Agency, Washington, DC. Available online at <https://www.epa.gov/enviro/greenhouse-gas-customized-search>. Accessed on October 4, 2016.

ICF International (2016). User's Guide for Estimating Emissions from Municipal Solid Waste Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

MSW (2011). 2011 Iowa Statewide Waste Characterization Study. Prepared by MidAtlantic Solid Waste Consultants for the Iowa Department of Natural Resources, Des Moines, Iowa. September 2011.

Waste: Wastewater Treatment

EPA (2002). Onsite Wastewater Treatment Systems Manual. #625-R-00-008. U.S. Environmental Protection Agency, Washington DC. Available online at <https://www.epa.gov/sites/production/files/2015-06/documents/2004_07_07_septics_septic_2002_osdm_all.pdf>.

EPA (2016a). Envirofacts Greenhouse Gas Customized Search. U.S. Environmental Protection Agency, Washington, DC. Available online at <https://www.epa.gov/enviro/greenhouse-gas-customized-search>. Accessed on October 4, 2016.

EPA (2016b). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014. #430-R-16-002. U.S. Environmental Protection Agency, Washington DC. Available online at <http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html >.

ICF International (2016a). State Inventory Tool – Wastewater Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 15, 2016.

ICF International (2016b). User's Guide for Estimating Methane and Nitrous Oxide Emissions from Wastewater Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

U.S. Census Bureau (2016). U.S. Census Quick Facts. U.S. Census Bureau, Washington DC. Available online at <http://quickfacts.census.gov/qfd/states/19000.html>. Accessed August 26, 2016.

LULUCF

DNR (2016). Tonnage Report Data. Iowa Department of Natural Resources, Des Moines, Iowa. Available online at <https://programs.iowadnr.gov/solidwaste/reports/index>. Accessed on September 21, 2016.

Flickinger, A. (2010). Iowa's Forests Today. Aron Flickinger, Special Projects Forester, Iowa Department of Natural Resources, Des Moines, Iowa. Available online at <http://www.iowadnr.gov/Conservation/Forestry/Forestry-Links-Publications/Iowa-Forest-Action-Plan>.

Hall, J. (2016). Personal communication. Jan Hall, Iowa Limestone Producers Association, Urbandale, Iowa. September 2, 2016.

Hannigan, E. (2014). Email correspondence. Emma Hannigan, Urban Forestry Coordinator, Iowa Department of Natural Resources, Des Moines, Iowa. October 15 and 16, 2014.

ICF International (2016). User's Guide for Estimating Emissions and Sinks from Land Use, Land-Use Change, and Forestry Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

IDALS (2016). Fertilizer Tonnage Distribution in Iowa for July 1, 2013 – June 30, 2014 and July 1, 2014 – June 30, 2015. Iowa Department of Agriculture and Land Stewardship, Commercial Feed and Fertilizer Bureau. Des Moines, Iowa. Available online at <http://www.iowaagriculture.gov/feedAndFertilizer/fertilizerDistributionReport.asp>.

Kantak, G. (2014). Email correspondence. Gail Kantak, Wildland Fire Supervisor, Iowa Department of Natural Resources, Des Moines, Iowa. November 10, 2014.

MSW (2011). 2011 Iowa Statewide Waste Characterization Study. Prepared by MidAtlantic Solid Waste Consultants for the Iowa Department of Natural Resources, Des Moines, Iowa. September 2011. Available online at <http://www.iowadnr.gov/Portals/idnr/uploads/waste/wastecharacterization2011.pdf >.

Reyes, A. (2011). Personal communication. Adriana Reyes, Geologist 3, Iowa Department of Transportation, Ames, Iowa. July 26, 2011.

Strait, R. et al. (2008). Final Iowa Greenhouse Gas Inventory and Reference Case Projections 1990 – 2025. Center for Climate Strategies, Washington DC. Available online at <http://www.iowadnr.gov/Environment/ClimateChange.aspx>.

USFS (2016). Forest Inventory Data Online (FIDO). Forest Service, U.S. Department of Agriculture, Washington DC. Available online at <http://apps.fs.fed.us/fia/fido/index.html>. Accessed on September 1, 2016.

Electricity Consumption

eGRID (2015) Emissions & Generation Resource Integrated Database – eGRID2012. EIA U.S. Environmental Protection Agency, Washington DC. Available online at <https://www.epa.gov/energy/egrid>. Accessed on September 22, 2016.

EIA (2016b) State Energy Data System (SEDS) 1960-2014 Completed Data File – Released June 29, 2016. Energy Information Administration, U.S. Department of Energy, Washington DC. Available online at <http://www.eia.gov/state/seds/seds-data-complete.cfm?src=email>. Accessed on September 2, 2016.

ICF International (2016a). State Inventory Tool – Electricity Consumption Module. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. May 9, 2016.

ICF International (2016b). User's Guide for Estimating Indirect Carbon Dioxide Equivalent Emissions from Electricity Consumption Using the State Inventory Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. February 2016.

IEDA (2016). Advancing Iowa's Electric Vehicle Market. Iowa Clean Cities Coalition, Iowa Economic Development Authority, Des Moines, Iowa. Available online at <http://www.iowaeconomicdevelopment.com/userdocs/documents/ieda/AdvancingIowasElectricVehicleMarketReport.pdf>.

IDOT (2016). 2015 Vehicle Registrations by County. Iowa Department of Transportation. Ames, Iowa. Available online at <http://www.iowadot.gov/mvd/stats/regis2015.pdf>. Accessed on September 22, 2016.

Forecasting

CAMD (2016). Clean Air Markets – Data and Maps. Clean Air Markets Division, U.S. Environmental Protection Agency, Washington D.C. Available online at <https://ampd.epa.gov/ampd/>. Accessed on November 3, 2016.

EIA (2016a) Annual Energy Outlook 2016 with Projections to 2040. Energy Information Administration, U.S. Department of Energy, Washington D.C. Available online at <http://www.eia.gov/forecasts/aeo/data.cfm#enconsec>.

EIA (2016b) Today in Energy. Energy Information Administration, U.S. Department of Energy, Washington D.C. October 12, 2016. Available online at <http://www.eia.gov/todayinenergy/detail.php?id=28312>.

ICF International (2014). State Inventory Tool – Projection Tool. Prepared for the State Climate and Energy Program, U.S. Environmental Protection Agency, Washington DC. December 1, 2014.

U.S. Census Bureau (2016). U.S. Census Quick Facts. U.S. Census Bureau, Washington DC. Available online at <http://quickfacts.census.gov/qfd/states/19000.html>. Accessed August 26, 2016.

Woods & Poole (2009). Projections of Total Population for U.S., Iowa, and its Counties: 2010-2040. Woods & Poole Economics, Inc. 2009. Available online at <http://www.iowadatacenter.org/browse/projections.html>.

Appendix A – Iowa GHG Emissions 2005 – 2015 by Sector[25]

Emissions ($MMtCO_2e$)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Agriculture	32.14	34.25	38.73	34.81	34.63	34.07	36.61	34.90	**35.22**	**36.26**	37.23
Enteric Fermentation	5.95	6.35	6.62	6.77	6.74	6.67	7.04	6.95	7.02	**6.85**	7.02
Manure Management	6.77	6.80	7.48	8.19	8.25	7.53	8.34	8.40	**8.59**	**8.47**	8.75
Agricultural Soil Management	19.42	21.10	24.63	19.85	19.63	19.86	21.22	19.56	19.61	**20.94**	21.46
Burning of Crop Residues	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Fossil Fuel Combustion	60.90	60.68	66.26	69.53	65.38	70.89	70.29	65.40	64.56	**66.25**	60.42
Electric Generating Facilities	36.84	36.35	40.04	41.78	37.71	42.33	38.38	35.76	33.06	33.44	29.46
Residential, Commercial, Industrial	24.07	24.32	26.21	27.75	27.66	28.56	31.31	29.65	31.50	**32.81**	30.96
Industrial Processes	4.58	4.71	4.70	4.93	4.23	4.80	4.49	5.18	5.20	**4.91**	5.01
Ammonia & Urea Production	1.01	0.91	0.95	0.87	0.60	0.84	0.75	0.85	0.88	0.86	0.81
Cement Manufacture	1.27	1.29	1.27	1.31	0.84	0.72	0.79	1.27	1.41	1.38	1.50
Electric Power Transmission & Distribution Systems	0.12	0.12	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.06	0.06
Iron and Steel Production	0.13	0.13	0.13	0.12	0.09	0.23	0.20	0.23	0.19	0.18	0.16
Lime Manufacture	0.18	0.17	0.16	0.17	0.13	0.18	0.18	0.18	0.16	0.17	0.13
Limestone and Dolomite Use	0.18	0.29	0.24	0.25	0.29	0.39	0.16	0.15	0.33	**0.21**	0.21
Nitric Acid Production	0.68	0.75	0.81	0.90	0.90	0.99	0.94	0.99	0.83	**0.69**	0.77
ODS Substitutes	0.99	1.01	1.01	1.20	1.27	1.36	1.39	1.44	1.33	**1.34**	1.34
Soda Ash Consumption	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LULUCF[26]	-20.54	-5.79	3.41	-3.91	-5.00	-2.00	0.66	0.48	**-0.74**	**3.29**	3.18
Forest Carbon Flux	-21.24	-6.53	2.70	-4.48	-5.47	-2.68	-0.14	-0.47	-1.02	**3.04**	3.04
Liming of Agricultural Soils	0.42	0.45	0.37	0.28	0.27	0.47	0.51	0.65	0.47	0.41	0.34
Urea Fertilization	0.15	0.15	0.15	0.15	0.12	0.11	0.12	0.13	**0.11**	**0.15**	0.15
Urban Trees	-0.25	-0.25	-0.25	-0.26	-0.26	-0.28	-0.28	-0.28	-0.74	-0.74	-0.74
Yard Trimmings and Food Scraps Stored in Landfills	-0.09	-0.09	-0.08	-0.09	-0.10	-0.10	-0.13	-0.12	-0.11	-0.12	-0.12
Fertilization of Settlement Soils	0.46	0.48	0.53	0.49	0.44	0.48	0.56	0.57	0.55	0.55	0.51

[25] Totals may not equal the exact sum of subtotals in this table due to independent rounding. Values that are bolded have been adjusted since the previous 2014 inventory published by the Department in December 2015. The adjustments are described in detail in this document.

[26] Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

Emissions (MMtCO$_2$e)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Natural Gas Transmission & Distribution	1.15	1.15	1.16	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.17
Transmission	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Distribution	0.50	0.50	0.50	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.51
Transportation	21.88	22.38	22.81	21.97	21.42	22.07	**19.56**	**19.58**	**19.50**	**19.88**	20.22
Waste	2.62	2.56	2.60	2.62	2.58	**1.77**	**1.76**	**1.90**	**1.72**	**1.70**	1.82
Solid Waste	2.17	2.11	2.14	2.15	2.12	**1.30**	**1.35**	**1.48**	**1.31**	**1.30**	1.42
Wastewater	0.45	0.45	0.45	0.47	0.47	**0.47**	**0.41**	**0.42**	**0.42**	**0.40**	0.40
Gross Emissions	123.27	125.73	139.67	135.04	129.41	**134.77**	**134.55**	**128.62**	**127.38**	**133.47**	129.05
Sinks	-20.54	-5.79		-3.91	-5.00	-2.00			-0.74		
Net Emissions	102.73	119.93	139.67	131.13	124.42	**132.77**	**134.55**	**128.62**	**126.64**	**133.47**	129.05
% Change from Previous Year (Gross)		+1.99%	+11.09%	-3.31%	-4.17%	**+4.14%**	**+1.34%**	**-4.41%**	**-0.97%**	**+4.78%**	-3.31%
% Change from 2005 (Gross)		+1.99%	+13.30%	+9.54%	+4.98%	**+9.32%**	**+9.15%**	**+4.34%**	**+3.33%**	**+8.27%**	+4.69%

Appendix B – Iowa GHG Emissions 2005 – 2015 by Pollutant[27]

Emissions ($MMtCO_2e$)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Gross CO_2	84.68	85.03	93.93	93.50	88.07	94.57	**91.30**	**87.00**	**86.41**	**91.07**	85.58
Net CO_2	63.68	78.75	93.93	89.10	82.64	92.08	**91.30**	**86.91**	**85.12**	**91.07**	85.58
Stationary Fossil Fuel Combustion	60.60	60.37	65.93	69.19	65.06	70.45	**69.85**	**65.00**	**64.17**	**65.86**	60.06
Transportation	21.25	21.82	22.31	21.54	21.03	21.72	**19.26**	**19.30**	**19.25**	**19.63**	19.99
Industrial Processes	2.80	2.82	2.78	2.75	1.97	2.38	2.09	2.69	2.98	2.83	2.85
Solid Waste	0.03	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
LULUCF[28]	-21.00	-6.28	2.89	-4.40	-5.43	-2.49	0.09	-0.09	**-1.29**	**2.75**	2.67
CH_4	15.62	15.94	16.90	17.75	17.74	**16.64**	**17.12**	**17.35**	**17.46**	**17.17**	17.71
Stationary Fossil Fuel Combustion	0.08	0.08	0.08	0.08	0.08	0.17	0.17	0.16	0.15	**0.15**	0.14
Transportation	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	**0.03**	0.03
Natural Gas and Oil Transmission and Distribution	1.15	1.15	1.16	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.17
Enteric Fermentation	5.95	6.35	6.62	6.77	6.74	6.67	7.04	6.95	7.02	**6.85**	7.02
Manure Management	5.89	5.86	6.50	7.18	7.23	6.94	7.04	**7.26**	**7.47**	**7.36**	7.64
Burning of Agricultural Crop Residues	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Solid Waste	2.14	2.09	2.12	2.13	2.10	**1.28**	**1.33**	**1.46**	**1.30**	**1.29**	1.41
Wastewater	0.36	0.37	0.37	0.38	0.38	0.37	0.32	0.32	0.32	0.30	0.30
N_2O	22.33	24.11	27.73	22.98	22.68	**22.61**	**24.66**	**22.87**	**22.68**	**23.84**	24.37
Stationary Fossil Fuel Combustion	0.23	0.23	0.25	0.26	0.24	0.27	0.27	0.25	0.25	**0.24**	0.22
Transportation	0.59	0.52	0.46	0.40	0.36	0.32	0.28	0.25	0.20	**0.22**	0.20
Industrial Processes	0.68	0.75	0.81	0.90	0.90	0.99	0.94	0.99	0.86	**0.69**	0.77
Manure Management	0.88	0.94	0.97	1.01	1.02	0.59	1.30	1.14	**1.12**	**1.10**	1.11
Agricultural Soil Management	19.41	21.09	24.63	19.84	19.63	19.86	21.22	19.56	19.61	**20.94**	21.46
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O from Settlement Soils	0.46	0.48	0.53	0.49	0.44	0.48	0.56	0.57	0.55	0.55	0.51
Solid Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wastewater	0.08	0.09	0.09	0.09	0.09	**0.09**	**0.10**	**0.10**	**0.10**	**0.10**	0.10

[27] Totals may not equal the exact sum of subtotals in this table due to independent rounding. Values that are bolded have been adjusted since the previous 2014 inventory published by the Department in December 2015. The adjustments are described in detail in this document.

[28] Carbon emitted from the LULUCF sector is shown as a positive number. Carbon stored by the LULUCF sector is shown as a negative number.

Emissions (MMtCO$_2$e)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
HFC, PFC, and SF$_6$	1.11	1.13	1.11	1.29	1.35	1.44	1.46	1.50	1.39	**1.39**	1.39
Industrial Processes	1.11	1.13	1.11	1.29	1.35	1.44	1.46	1.50	1.39	**1.39**	1.39
Gross Emissions	123.73	126.21	139.68	135.53	129.85	**135.25**	**134.54**	**128.72**	**127.94**	**133.47**	129.05
Sinks	-21.00	-6.28		-4.40	-5.43	-2.49		-0.09	**-1.29**		
Net Emissions (Sources and Sinks)	102.73	119.93	139.68	131.13	124.42	**132.76**	**134.54**	**128.63**	**126.65**	**133.47**	129.05